Effect of 1-MCP, production region, harvest time, orchard slope and fruit canopy position on 'Hass' avocado colour development during ripening

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ABSTRACT

The aim of this work was to investigate the role of 1-MCP, production region, harvest time, orchard slope and fruit canopy position on colour development of 'Hass' avocado fruit during ripening. 'Hass' avocado fruit were harvested from Tzaneen area for the 1-MPC trial, and from both Tzaneen and Mpumalanga areas for the orchard slope and fruit canopy position experiments. Results further confirmed that de-synchronisation of 'Hass' skin colour with fruit softening is predominantly an early-season phenomenon. Therefore, postharvest treatments such as 1-MCP had no effect on 'Hass' colour change, irrespective of harvest time. Interestingly, there seem to be a significant difference in 'Hass' skin colour development for fruit from Tzaneen area when compared with fruit from the Hazyview area. Tzaneen fruit showed higher skin colour de-synchronisation, even during late-harvest when compared with Mpumalanga fruit. Furthermore, inside tree canopy fruit harvested from upper orchard slope showed higher de-synchronisation of skin colour even for mid- and late-season fruit, especially fruit sourced from Tzaneen production area.

INTRODUCTION

The South African avocado industry continues to face challenges of variable skin colouring with 'Hass' avocado fruit during ripening. 'Hass' avocado fruit are supposed to change skin colour from green to purple/black during ripening (Cox *et al*., 2014). However, overseas marketers and consumers have experienced a challenge with certain consignments from South Africa with respect to skin colour change as a ripening indicator parameter. Such quality parameter variation compromises the industry's international standings.

So far, there is no detailed understanding of the de-synchronised colour development phenomenon in 'Hass' avocado fruit during ripening. According to Donetti and Terry (2014), fruit from South Africa showed worse skin colour development when compared with fruit from Spain, but mainly at lower ripening temperatures (Cox *et al*., 2004). In the 2014 season the South African Avocado Growers' Association (SAAGA) commissioned the Agricultural Research Council's Institute for Tropical and Subtropical Crops (ARC-ITSC) to research the problem of colour development on 'Hass' avocado fruit. First season (2014) results indicated that the 'Hass' skin colour problem is primarily associated with: 1) fruit maturity (early season fruit); 2) Manifestation of chilling damage, especially with early season fruit; 3) Mainly fruit from orchards with slopes, with fruit from lower part of slopes showing significantly high colour development problem; 4) To a lesser extent, lower ripening temperatures, which only affect the rate of colouring (Mathaba *et al*., 2015). Furthermore, other researchers that have researched the effect of 1-MCP (1-Methylcyclopropene) on colouring of 'Hass' avocado fruit found that 1-MCP had an insignificant effect on colour development of 'Hass' fruit during ripening (Woolf *et al*., 2005).

The aims of this continuing research were therefore: 1) To investigate the effect of 1-MCP and harvest time; 2) the effect of production region, harvest time and orchard slope; and 3) the effect of production region, harvest time and fruit canopy position on 'Hass' avocado skin colour development during ripening.

MATERIALS AND METHODS

1-MCP and harvest time experiment

'Hass' avocado fruit were harvested during mid- (June 2015) and late (August 2015) season from the Tzaneen area in Limpopo province, thereafter, sorted and treated with 1-MCP at 300 ppm. After 1-MCP treatments, fruit were transported to the ARC-ITSC's postharvest laboratory for cold storage. 1-MCP treated and untreated (control) fruit were stored at 5.5°C for 28 days and afterwards ripened at 21°C.

Production area, harvest time and orchard slope experiment

Avocado 'Hass' fruit were havested early- (April 2015), mid- (June 2015) and late (August 2015) season from the Tzaneen area in Limpopo province and Hazyview area in Mpumalanga province. After harvesting, fruit were transported to the ARC-ITSC's postharvest laboratories for sorting and grading; afterwards, stored at 5.5°C for 28 days. After storage, fruit were ripened at 21°C.

Production area, harvest time and fruit canopy position experiment

'Hass' avocado fruit were harvested early- (April 2015) and mid- (June 2015 and August 2015) season from the Tzaneen area in Limpopo province and Hazyview area in Mpumalanga province. Fruit were harvested from outside and inside tree canopy, thereafter transported to the ARC-ITSC's postharvest laboratory in Nelspruit for sorting, grading and storage at 5.5°C for 28 days. After withdrawal from cold storage, fruit were ripened at 21°C.

Data collection and statistical analysis

During ripening at 21°C, fruit were evaluated for the following quality parameters: firmness, subjective- (eye colour) (Plate 1) and objective colour (L – Lightness, C – Chroma and h° – Hue angle) using a Chroma meter. Collected data was subjected to statistical analysis using Genstat version 16.

RESULTS AND DISCUSSION

Effect of 1-MCP and harvest time on colour development of 'Hass' avocado fruit

'Hass' avocado fruit harvested during mid-season and treated with 1-MCP fully ripened at day 8 when compared with non 1-MCP treated fruit, which fully ripened at day 6. Even though days to ripening varied, no significant differences were observed with respect to skin eye colour (≈4.0). Fruit reached a required purple colour and ripeness percentages (Table 1). Furthermore, subjective colour parameters (L, C and h°) also showed no significant differences for

Plate 1. 'Hass' avocado skin colour change rating used during ripening in the study.

Table 1. Effect of 1-MCP, harvest time and ripening time on colour development of 'Hass' avocado fruit ripened at 21°C.

Harvest time		No 1-MCP						1-MCP					
				Colour parameters						Colour parameters			
		Firmness	Ripening	Eye colour	L	C	h°	Firmness	Ripening	Eye colour	L	C	h°
Mid	0	61.39	0.00	1.00	34.16	23.65	146.42	63.19	0.00	1.13	34.99	26.28	141.81
	2	52.14	0.00	1.67	41.15	19.58	118.48	56.39	0.00	1.39	36.10	20.53	128.04
	4	29.91	29.67	3.74	34.17	14.45	50.42	42.56	0.00	2.83	36.00	19.16	68.92
	6	18.23	96.00	3.96	28.52	7.24	84.54	27.64	40.67	3.78	28.93	7.56	85.07
	8	*	*	*	*	*	*	19.31	88.67	4.33	27.83	8.21	79.58
	10	*	*	*	*	*	*	*	*	*	*	*	*
Late	0	58.41	0.00	1.00	35.91	26.92	147.67	58.15	0.00	1.00	35.66	27.10	147.53
	2	54.12	0.00	1.06	30.95	13.21	142.48	56.89	0.00	1.00	31.62	14.32	142.40
	4	43.66	0.00	2.30	28.40	8.72	109.60	53.68	0.00	1.07	31.21	13.93	139.91
	6	19.26	70.67	4.06	29.42	8.76	76.05	54.06	0.00	1.20	36.37	21.13	143.68
	8	*	*	*	*	*	*	48.58	0.00	1.89	33.75	16.74	128.08
	10	*	*	*	*	*	*	37.59	26.00	3.33	30.93	11.66	88.94
	12	*	*	*	*	*	*	23.15	53.67	4.20	28.94	6.79	83.12

* Fruit ripened and experiment terminated

mid-season fruit and 1-MCP or non 1-MCP treated fruit. All objective colour parameters indicated fully developed purple colour during ripening (Table 1).

Late-season 'Hass' avocado fruit treated with or without 1-MCP also showed no significant difference in skin eye colour (>4.00) and fully ripened and purple coloured at day 6 and 12, respectively (Table 1). Moreover, subjective colour parameters (L, C and h°) also indicated full purple colour development and ripeness. Therefore, 1-MCP treatment and harvest season (mid and late), had no effect on mid- and late-season colour development of 'Hass' avocado fruit, however, expectedly affected the rate ripening and colour development.

Effect of production site, harvest time and orchard slope on colour development of 'Hass' avocado fruit

Lower orchard slope

Early-season 'Hass' fruit harvested from lower slopes fully ripened while skin colour was still in the olive green stage (eye colour ≈3), irrespective of production site (Tzaneen or Hazyview). Subjective colour parameters (L, C and h°) also indicated an olive green colour stage when early-season fruit were fully ripened (firmness <25) (Table 2). Interestingly, mid-season fruit from Tzaneen behaved similar to early-season fruit, being fully ripened at forest green eye colour rating (≈2.10), and objective colour rating also supported eye colour rating (forest green) when fruit were fully ripened (average firmness = 27.13). Contrarily, mid-season fruit from Hazyview significantly improved in skin eye colour (purple = 4.63) and objective colour rating (L, C and h°) when compared with fruit from Tzaneen (forest green) (Table 2). Late-season fruit from Tzaneen did not show a significant improvement in skin colour development, as eye colour only reached olive green (3.20) stage when fruit were fully ripened (firmness = 21.65) at day 4. Furthermore, objective colour parameters (L, C and h°) also confirmed colour development recalcitrance of late-season fruit from Tzaneen. On the other side, fruit harvested from Hazyview showed skin colour development as indicated by eye (purple = 4.14) and all subjective colour parameters (L, C and h°), and firmness of 23.37 when fruit were fully ripened at day 4 (Table 2).

Upper orchard slope

Fruit harvested from Tzaneen area showed no improvement in skin colour; irrespective of harvest-time. 'Hass' fruit skin eye colour for Tzaneen fruit harvested during early-, mid- and late-season was 3.15, 2.32 and 3.18, respectively (Table 3). When firmness was indicative of maximum ripeness, both subjective (average eye colour was at olive green stage) and all objective colour parameters (L, C and h°) were showed olive green stage throughout harvest season (Table 3). While early-season fruit from Hazyview area behaved similar to Tzaneen fruit throughout harvest season, whereby, fruit remained forest to olive green when fully ripened. Interestingly, 'Hass' fruit from Hazyview area developed skin colour as expected (colour improving with harvest time), with early-season fruit showing strong colour de-synchronisation during ripening. Early-season fruit had an average skin eye colour rating of 2.62

Table 2. Effect of production region, harvest and ripening time on colour development of 'Hass' avocado fruit harvest from lower orchard slope.

		Limpopo - Tzaneen						Mpumalanga - Hazyview					
Harvest time	Ripening time (days)			Colour parameters						Colour parameters			
		Firmness	Ripening	Eye colour	L	C	h°	Firmness	Ripening	Eye colour	L	C	h°
Early	0	56.21	0.00	1.00	34.65	20.13	153.08	42.85	0.00	1.00	33.16	16.24	168.32
	2	35.17	4.33	1.03	33.28	13.53	170.76	30.91	24.33	2.35	30.38	10.43	123.29
	4	24.78	74.33	3.22	31.00	11.65	91.04	22.84	56.67	2.70	29.82	9.61	114.51
	6	*	*	*	*	*	*	*	*	*	*	*	*
	8	*	*	*	*	*	*	*	*	*	*	*	*
Mid	0	45.18	0.00	1.00	35.17	14.87	158.87	57.17	0.00	1.00	35.17	14.87	158.87
	2	34.93	2.00	1.98	33.38	10.69	126.44	51.73	0.00	1.98	33.38	10.69	126.44
	4	27.13	57.67	2.10	33.09	10.42	126.37	37.51	8.67	2.10	33.09	10.43	126.47
	6	*	*	*	*	*	*	28.26	49.00	3.80	28.71	4.37	99.14
	8	*	*	*	*	*	*	23.06	75.67	4.63	27.03	2.80	89.65
Late	0	53.16	0.00	1.97	32.92	15.74	120.55	61.53	0.00	1.70	33.51	14.87	135.17
	2	37.80	5.33	2.57	32.76	9.65	110.25	41.11	1.00	2.85	30.83	6.02	104.03
	4	21.56	83.33	3.20	30.73	8.14	96.47	23.37	70.00	4.15	24.33	4.67	75.91
	6	*	*	*	*	*	*	*	*	*	*	*	*
	8	*	*	*	*	*	*	*	*	*	*	*	*

* Fruit ripened and experiment terminated

Table 3. Effect of production region, harvest and ripening time on colour development of 'Hass' avocado fruit harvest from upper orchard slope.

Harvest time	Ripening time (days)	Limpopo - Tzaneen						Mpumalanga - Hazyview					
				Colour parameters						Colour parameters			
		Firmness	Ripening	Eye colour	L	C	h°	Firmness	Ripening	Eye colour	L	C	h°
Early	0	55.58	0.00	1.22	35.91	22.09	146.12	48.42	0.00	1.00	33.41	15.76	164.11
	2	29.65	17.00	1.17	32.31	12.53	164.26	33.94	5.67	2.25	30.83	13.18	118.76
	4	21.75	78.33	3.15	30.22	8.87	97.91	25.41	58.67	2.62	30.43	10.97	111.27
	6	*	*	*	*	*	*	*	*	*	*	*	*
	8	*	*	*	*	*	*	*	*	*	*	*	*
Mid	0	45.65	0.00	1.00	34.16	12.81	161.93	65.50	0.00	1.00	36.15	19.98	147.12
	2	34.72	4.33	2.05	32.37	9.32	126.70	58.91	0.00	1.50	34.47	15.80	135.65
	4	26.49	60.00	2.32	31.74	9.03	119.12	42.70	0.00	3.48	31.14	9.75	71.51
	6	*	*	*	*	*	*	31.83	41.33	4.13	28.76	7.43	79.56
	8	*	*	*	*	*	*	23.06	75.09	5.00	26.99	5.85	70.06
Late	0	57.19	0.00	1.97	32.92	15.74	120.55	61.06	0.00	1.27	34.53	17.87	145.69
	2	44.30	1.00	2.55	32.75	9.60	110.21	35.16	14.33	2.47	26.72	6.72	111.06
	4	20.93	98.00	3.18	30.77	8.14	96.59	21.47	85.67	3.80	24.70	5.22	79.10
	6	*	*	*	*	*	*	*	*	*	*	*	*
	8	*	*	*	*	*	*	*	*	*	*	*	*

* Fruit ripened and experiment terminated

Table 4. Effect of production region, harvest and ripening time on colour development of 'Hass' avocado fruit harvested from inside tree canopy.

Harvest time	Ripening time (days)	Limpopo – Tzaneen Inside Canopy						Mpumalanga – Hazyview Inside Canopy					
				Colour parameters						Colour parameters			
		Firmness	Ripening	Eye colour	L	C	h°	Firmness	Ripening	Eye colour	L	C	h°
Early	0	56.19	0.00	1.05	36.10	23.44	149.43	48.59	0.00	1.00	33.56	17.15	168.68
	2	30.32	13.83	1.15	32.88	13.66	168.18	34.29	10.67	2.14	30.55	11.39	129.98
	4	22.72	83.50	3.02	31.35	10.97	101.22	24.18	76.33	2.68	30.55	10.76	111.65
	6	*	*	*	*	*	*	*	*	*	*	*	*
	8	*	*	*	*	*	*	*	*	*	*	*	*
Mid	0	46.99	0.00	1.00	34.77	14.01	161.25	68.88	0.00	1.00	35.72	20.15	146.75
	2	35.09	3.67	2.04	32.34	9.68	127.46	61.65	3.17	1.62	34.39	15.74	126.58
	4	26.11	60.50	2.41	31.81	9.64	115.36	40.64	58.83	3.51	31.23	9.55	65.81
	6	*	*	*	*	*	*	27.90	60.36	4.18	28.47	6.42	73.61
	8	*	*	*	*	*	*	23.60	80.50	5.01	26.95	4.83	65.18
Late	0	58.44	0.00	1.12	34.53	19.91	146.01	61.75	0.00	1.30	33.84	19.44	155.04
	2	43.08	3.17	2.33	31.12	10.20	112.09	35.78	3.17	1.97	34.67	13.15	122.07
	4	23.43	82.67	3.48	28.06	7.14	87.41	20.41	90.67	3.30	30.98	9.45	92.40
	6	*	*	*	*	*	*	*	*	*	*	*	*
	8	*	*	*	*	*	*	*	*	*	*	*	*

* Fruit ripened and experiment terminated

Table 5. Effect of production region, harvest and ripening time on colour development of 'Hass' avocado fruit harvested from outside tree canopy.

Harvest time	Ripening time (days)	Limpopo – Tzaneen Outside Canopy						Mpumalanga – Hazyview Outside Canopy					
				Colour parameters						Colour parameters			
		Firmness	Ripening	Eye colour	L	C	h°	Firmness	Ripening	Eye colour	L	C	h°
Early	0	48.59	0.00	1.11	35.28	21.11	149.60	45.63	0.00	1.00	33.28	16.00	166.21
	2	34.29	26.50	1.10	32.80	13.03	167.51	32.43	15.00	2.30	30.60	11.81	121.02
	4	24.18	74.17	3.18	30.61	10.26	94.47	24.12	57.67	2.66	30.13	10.29	112.89
	6	*	*	*	*	*	*	*	*	*	*	*	*
	8	*	*	*	*	*	*	*	*	*	*	*	*
Mid	0	68.88	0.00	1.00	34.66	13.84	160.40	61.34	0.00	1.00	35.66	17.43	153.00
	2	61.65	3.17	2.02	32.88	10.01	126.57	55.32	0.00	1.74	33.93	13.25	131.05
	4	40.64	58.83	2.21	32.42	9.72	122.74	40.11	4.33	2.79	32.11	10.09	98.99
	6	27.90	60.36	4.01	28.77	5.16	88.97	30.04	45.17	4.13	28.79	7.44	79.63
	8	23.60	88.52	4.84	27.19	3.59	79.51	24.30	73.33	5.00	27.16	5.87	70.15
Late	0	61.75	0.00	1.97	32.92	15.74	120.55	55.18	0.00	1.48	34.02	16.37	140.56
	2	35.78	21.17	2.56	32.76	9.63	110.23	41.05	7.67	2.66	26.50	6.37	107.54
	4	20.41	86.83	3.19	30.75	8.14	96.53	21.24	77.83	3.98	24.52	4.94	77.51
	6	*	*	*	*	*	*	*	*	*	*	*	*
	8	*	*	*	*	*	*	*	*	*	*	*	*

* Fruit ripened and experiment terminated

and objective colour parameters (L, C and h°) clearly indicating forest to olive green skin colour (Table 3). Mid- and late-season fruit from Hazyview significantly improved in both subjective (eye colour) and objective (L, C and h°) colour parameters with highest ripening percentages (Table 3).

Effect of production site, harvest time, canopy position and ripening time on colour development of 'Hass' avocado fruit

Inside canopy fruit

'Hass' avocado fruit sourced from Tzaneen and harvested from inside tree canopy showed de-synchronised skin colour development, irrespective of harvest time and ripening time (Table 4). Fruit skin eye colour for early-, mid- and late-season was 3.02, 2.41 and 3.48, respectively. Furthermore, inside canopy fruit from Tzaneen area also showed higher objective colour parameters (L, C and h°), irrespective of harvest season, which further proved high colour de-synchronisation during ripening for such fruit. Whereas, inside canopy 'Hass' fruit from Hazyview area showed an improvement in skin colour development, especially mid-season fruit with an eye colour of 5.01 (black) (Table 4). Subjective colour parameters (L, C and h°) also correlated with colour improvement of inside canopy mid-season fruit sourced from Hazyview area. Late-season fruit sourced from Hazyview area showed an improvement in skin colour change when compared with Tzaneen fruit.

Outside canopy fruit

In general, outside canopy 'Hass' fruit showed an improved skin colour development for both production sites (Tzaneen and Hazyview area) (Table 5). However, mid-season fruit showed a significant skin colour development with an eye colour of 4.84 and 5.00 for Tzaneen and Hazyview areas. Interestingly, fruit harvested from Hazyview area maintained higher skin eye colour (3.98 ≈purple) even during late-season, which was not the case with fruit sourced from Tzaneen area (Table 5). In addition, objective colour parameters (L, C and h°) showed skin colour improvement for mid-season fruit from both production areas and late-season fruit from Hazyview when fruit were fully ripened (Table 5).

CONCLUSION

- The problem of skin colour development during ripening of 'Hass' avocado fruit continues to be predominantly an early-season occurrence, irrespective of production area, orchard slope, fruit canopy position, ripening temperature or any postharvest treatment such as 1-MCP.
- Production site seems to play a role in the 'Hass' skin colouring problem, with fruit from Tzaneen showing higher de-synchronised colour change even during mid- and late-season.
- Inside canopy fruit seems to display skin colour de-synchronisation even during mid- and late-season, whereby colour change problems supposed to be at minimal depending on production site.

- In addition, fruit harvested from lower parts of orchard slopes seem to show skin colour de-synchronisation when compared with fruit harvested from upper parts of orchard slope but is production site dependent.

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