



Article

Non-Structural Carbohydrate Composition of ‘Hass’ Avocado Fruit Is Affected by Maturity, Storage, and Ripening

Jeremy Burdon ^{1,*} , David Billing ¹, Judith Bowen ¹ and Helen Boldingh ² ¹ The New Zealand Institute for Plant and Food Research Limited, Private Bag 92169, Victoria Street West, Auckland 1142, New Zealand; david.billing@plantandfood.co.nz (D.B.)² The New Zealand Institute for Plant and Food Research Limited, Private Bag 3230, Waikato Mail Centre, Hamilton 3240, New Zealand; helen.boldingh@plantandfood.co.nz

* Correspondence: jeremy.burdon@plantandfood.co.nz

Abstract: Avocado fruits are considered unusual because of the large amounts of oil and seven-carbon (7-C) carbohydrates (mannoheptulose and perseitol) in the fruit’s flesh and skin. The fruit may be held on the tree unripe until required for marketing, and in some producing regions, this may extend past the next flowering period. This prolonged period on the tree is associated with increased oil content and decreased 7-C carbohydrates. There has been relatively less research into soluble hexose sugars and starch. In this research, the inter-relationships between fruit maturation, storage, and ripening have been investigated for both 7-C and six-carbon non-structural carbohydrates using ‘Hass’ fruit harvested from the same trees between 11 and 14 months after flowering. Significant differences were identified in both fruit flesh and skin for most compounds, affected by maturity, storage, and ripening. It is concluded that the non-structural carbohydrate composition of ‘Hass’ fruit is variable, with significant changes occurring associated with maturation, storage, and ripening. The compositions of the flesh and skin tissues are not consistently proportionate. Maturation provides the initial baseline composition from which any further change through storage or ripening can occur. The changes with maturation appear to be associated with the tree’s phenology, with tree-to-tree differences in the timing or degree of change.

Keywords: *Persea*; mannoheptulose; perseitol; glucose; fructose; sucrose; starch

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1. Introduction

Avocado (*Persea americana* Mill.) is a major commercial fruit crop, with the ‘Hass’ cultivar dominating the global trade. Avocado fruits are considered unusual in two ways. First, they accumulate large amounts of oil in the flesh and, second, for the presence of large amounts of the seven-carbon (7-C) carbohydrate mannoheptulose and its 7-C sugar alcohol perseitol in both the vegetative tissues and fruit [1,2].

The oil content of the fruit is significant for the eating quality and, hence, is used as a harvest index [3]. Too little oil is usually defined as below ~11–13% oil content (estimated as 22–24% dry matter), and the fruit is watery and insipid. To this end, dry matter is an indicator of the potential eating quality of the fruit, although it is often referred to as a maturity index.

When considering carbohydrates, it is common to split them into structural (cell-wall structure, cellulose, hemicellulose, and pectin) and non-structural, usually the common soluble sugars and starch-based on six-carbon (6-C) (hexose) molecules. While 7-C (heptose) sugars are common at low concentrations in higher plants, algae, fungi, and bacteria [4], their presence in high concentrations in avocado fruit is unusual.

There is, therefore, an inherent interest in the 7-C compounds, although their function is unclear [5,6]. Suggestions have included their being modulators of carbon flux during fruit growth and development and protectors against reactive oxidation damage [7], associated with an energy source and fruit quality [8], or with fruit ripening and its inhibition [5].

There has also been an assumption that there is some special role in the fruit and that more may be better for the fruit's commercial performance [9,10]. Both mannoheptulose and perseitol have been reported to decrease with ripening [2,5,11,12].

The 6-C sugars in avocado fruit are reported less frequently, and the presence of starch in the fruit, despite it having long been reported [13], is largely ignored in favour of reports on the oil content of the fruit and the role of 7-C carbohydrates. More recently, the use of measurement of the avocado fruit's total soluble solids (largely soluble sugars) in juice, by refractometer, has been suggested as a method for crop estimation and orchard management [14]. It has also been suggested as being indicative of fruit maturation and as a potential tool for the prediction of ripening [15,16]. However, earlier observations on soluble solids content in late-maturing 'Hass' fruit showed little consistent change with time on the tree or association with fruit quality [17,18]. Where avocado starch is mentioned in the scientific literature, it tends to be associated with seed starch use in waste streams for commercial processes (e.g., [19]), food or cosmetic uses [20], or its role in flowering and the fate of flowers and abscission [21]. The interconversion between 6-C and 7-C carbohydrates has been suggested as a mechanism to maintain the fruit energy and antioxidant status [6].

Increased amylase activity and reduced starch content have been associated with fruit ripening, as measured by fruit softening [13]. Also, the whole ripening process was coincident with increased ethylene production and was accelerated by the addition of ethylene [13]. To this extent, the changes in starch and softening coincided with ethylene production and increased respiration, which are typical of a climacteric fruit [22].

As avocado is a climacteric fruit, there is a clearly defined pre-climacteric period preceding the climacteric period, when there is increased respiration and ethylene production associated with fruit ripening [22]. This characteristic is important in the commercial trade, with avocado fruit harvested in the pre-climacteric state being maintained unripe during storage and distribution [23] and being ripened thereafter, either for retail or by the consumer at home.

In this paper, the fruit flesh and skin concentrations of the non-structural carbohydrates mannoheptulose, perseitol, glucose, fructose, sucrose, and starch are presented from an investigation on the maturation, storage, and ripening of 'Hass' avocado fruit.

2. Materials and Methods

2.1. Fruit

Fruits were harvested from trees growing at the New Zealand Institute for Plant and Food Research Limited (Plant & Food Research) orchard in Te Puke, Bay of Plenty, New Zealand (37°49' S, 176°19' E). The trees were mature *Persea americana* 'Hass' on 'Duke 7' rootstocks, all ~30 years old. Fruits were harvested three times within the commercial harvest season, between early October and mid-January the following year, which were between 11- and 14-months post-flowering. The harvests were designated as early (Harvest 1; 10 October), mid (Harvest 2; 9 November) and late (Harvest 3; 11 January), with the same three trees harvested on each occasion. For each harvest, 20 fruits from each tree were transported immediately to the postharvest laboratories of Plant & Food Research, Auckland, arriving 4–5 h after harvest.

2.2. Treatments

Immediately on arrival, the fruits were split into 5 groups each of 12 fruits (three trees, four fruits per tree), maintaining tree identity, and allocated to one of four treatments, with the remaining 12 fruits used for destructive assessment of at-harvest dry matter content. Treatments were designated by ripeness as unripe or ripe, and storage as unstored or stored. The unstored unripe fruits were assessed immediately, and the unstored ripe fruits were allowed to ripen at 20 °C before assessment. Ripe fruits were assessed when determined as eating ripe by hand feel (~15 N by a 2 mm compression test—see methodology below). The stored unripe and ripe samples of fruit were held at 5 °C for 28 d in commercial packaging

before assessment. After storage, the fruits of the unripe sample were assessed immediately, and the ripe sample was assessed after holding at 20 °C until ripe.

2.3. Assessment Methodologies

The skin colour of unripe and ripe fruit was scored subjectively on a 0–100 scale: 0 = bright glossy green, 30 = olive green, 60 = wood brown, 80 = purple–brown and 100 = dull black [24].

Fruit ripeness (firmness) was measured by a 2 mm flat plate compression test using a Fruit Texture Analyser (GÜSS, model GS14, Strand, South Africa).

Flesh dry matter was quantified by drying 1 mm discs of mesocarp at 65 °C for 24 h. Each fruit was sampled at the widest part of the fruit by taking two 18 mm diameter core samples at 90° to each other. After discarding the seed, seed coat, and skin, the four cylinders of mesocarp were sliced into discs for drying.

2.4. Chemical Analysis

Sample extraction

The skin and flesh of individual fruits were separated, chopped, immediately frozen in liquid nitrogen, and ground to a fine powder. The skin was removed from unripe fruit with a potato peeler. The ground sample was maintained frozen at –80 °C until analysed.

Sample analysis

Soluble carbohydrate analysis included the addition of adonitol as an internal standard. Approximately 1 g of ground, frozen fresh tissue (accurate weight recorded) was transferred into a 15 mL plastic centrifuge tube with the addition of 5 mL 80% ethanol and incubated for 1 h at 60 °C. The samples were centrifuged at 5082 × *g* for 10 min at 4 °C. The supernatant was decanted, and the pellet resuspended in 5 mL 80% ethanol and centrifuged again. The supernatants were combined, and the pellet was resuspended in 2.5 mL 80% ethanol and centrifuged again. The third supernatant was combined with the first two, and the pellet was reserved. A sub-sample of the pooled supernatant of each sample was dried and solubilised in ultrapure water prior to quantification. The soluble carbohydrates were quantified using a DIONEX™ CarboPac™ PA20 column with amino trap guard against known standards using a Thermo Scientific Dionex™ ICS-5000+ Ion Chromatography System (Thermo Fisher Scientific, Waltham, MA, USA) with Reagent-Free™ IC (RFIC™).

Starch in the reserved pellet was quantified with a colourimetric assay. The pellet was transferred to an Erlenmeyer flask using RO water and autoclaved for 1 h to solubilise the starch. After cooling, the sample was incubated for 1 h at 60 °C with the addition of amyloglucosidase in 250 mM pH 4.6 acetate buffer. Trinder's reagent and phenol were incubated with a sub-sample of the enzymatically hydrolysed starch, and then, the absorbance of the resulting dye product was measured at 510 nm. The sample quantification was from a glucose standard curve run concurrently. The glucose concentration was converted to starch equivalents, expressed as mg/g starch, and corrected for the recovery of a starch standard that was run concurrently.

2.5. Statistical Analysis

Sample means were separated statistically for treatment effects by an analysis of variance (ANOVA; GenStat for Windows 17th Edition. VSN International, Hemel Hempstead, UK), with Tree as a statistical block. The presented data are the sample means. The means fitted from the ANOVA models showed the same trends. Error bars in the figures are standard errors of the mean (s.e.m.).

3. Results

At harvest, the fruit dry matters were, on average, 28.9% for H1, 30.6% for H2, and 36.9% for H3 (Table 1). The skin colour score was zero for all fruit from all harvests. For

all harvests, the average firmness was >90 N. The average fruit ripening time was ~12 to 14 days.

Table 1. Dry matter, skin colour, firmness, and time to ripen of ‘Hass’ avocado fruit from early (H1), mid (H2), or late (H3) harvests. Values are the means of 12 fruit (s.e.m.).

Harvest	Dry Matter (%)	Skin Colour (0–100 Scale)	Firmness (N)	Time to Ripe (Days)
H1	28.9 (1.7)	0	96.1 (3.1)	12.8 (0.5)
H2	30.6 (1.1)	0	105.9 (2.6)	11.8 (0.6)
H3	36.9 (1.2)	0	92.2 (2.8)	13.9 (0.5)

3.1. Fruit Mannoheptulose and Perseitol

The mannoheptulose and perseitol contents of the fruit flesh and skin showed similar responses to maturation, storage, and ripening (Figure 1, Tables 2 and 3). There were marked decreases in the concentrations of both mannoheptulose and perseitol with maturation and ripening (all $p < 0.001$). The storage effect was not consistent, and while the reduction in skin mannoheptulose was statistically significant ($p < 0.001$), the change in perseitol was not ($p = 0.772$) (Tables 2 and 3). The concentration of mannoheptulose in the skin was markedly higher than in the fruit flesh (up to 30 mg/g in the skin and up to 15 mg/g in the flesh). In contrast, the concentrations of perseitol in the skin tended to be lower than in the flesh.

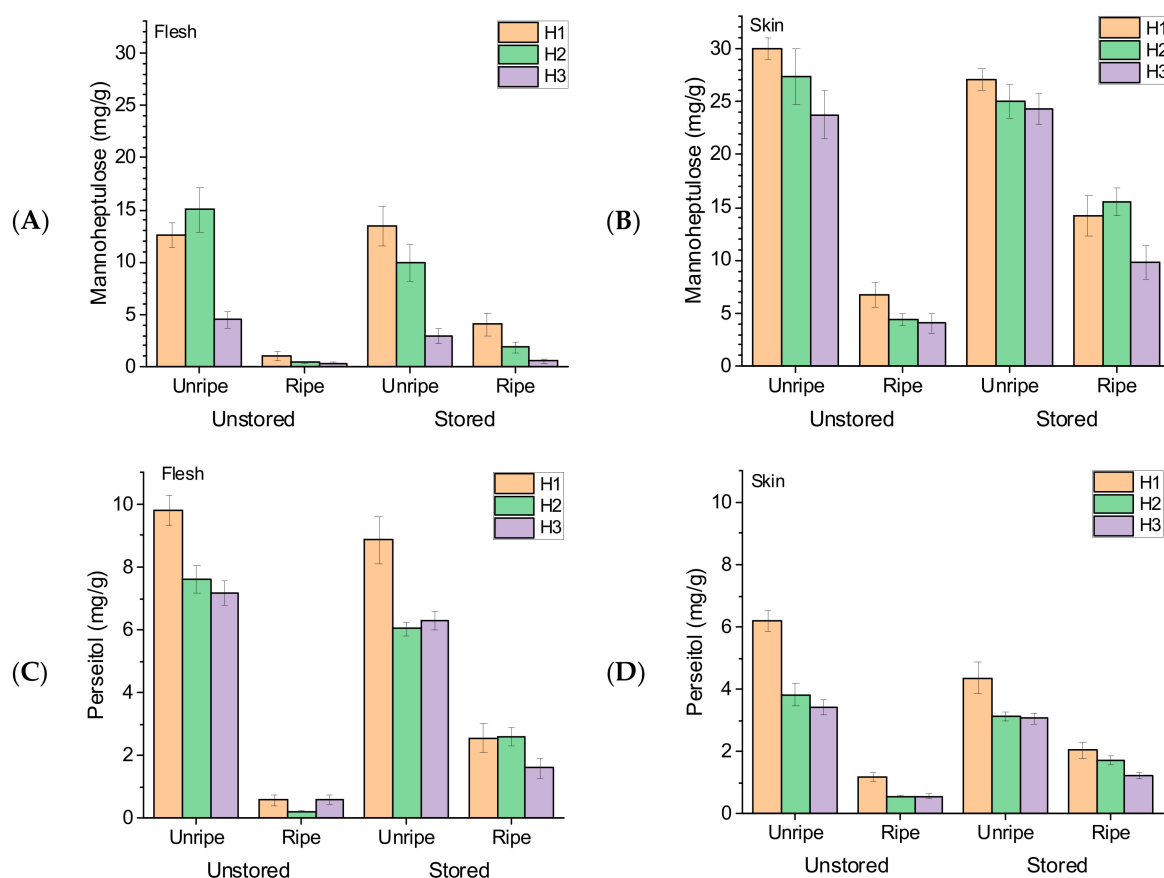


Figure 1. Mannoheptulose (A,B) and perseitol (C,D) in the flesh (A,C) and skin (B,D) of ‘Hass’ avocado fruit from three harvests (H1–H3) sampled when unripe or ripe before (Unstored) or after (Stored) storage for 28 days at 5 °C. Fruits were ripened at 20 °C. Values are the means of 12 fruit $\pm$ s.e.m.

Table 2. Analysis of variance *p*-values and variance ratios for maturity, ripeness, and storage effects on the non-structural carbohydrate composition of ‘Hass’ avocado fruit flesh. Fruits from three harvests were assessed when unripe or ripe, before or after storage for 28 days at 5 °C. Fruits were ripened at 20 °C.

Source of Variation	ANOVA <i>p</i> -Value					
	Mannoheptulose	Perseitol	Glucose	Fructose	Sucrose	Starch
Maturity (M)	<0.001	<0.001	<0.001	<0.001	0.168	0.181
Ripeness (R)	<0.001	<0.001	<0.001	<0.001	0.002	<0.001
Storage (S)	0.796	0.145	<0.001	0.029	0.168	<0.001
M.R	<0.001	<0.001	0.005	0.457	0.058	0.588
M.S	0.055	0.686	<0.001	<0.001	0.951	0.299
R.S	0.008	<0.001	0.064	<0.001	0.782	<0.001
M.R.S	0.260	0.166	0.048	0.001	0.006	0.083
Source of Variation	Variance Ratio					
	Mannoheptulose	Perseitol	Glucose	Fructose	Sucrose	Starch
Maturity (M)	29.86	19.52	22.34	20.28	1.81	1.73
Ripeness (R)	167.06	821.82	61.86	114.31	10.40	21.72
Storage (S)	0.07	2.15	17.21	4.85	1.92	96.14
M.R	15.84	11.83	5.62	0.79	2.92	0.53
M.S	2.97	0.38	9.16	7.87	0.05	1.22
R.S	7.15	44.76	3.48	16.62	0.08	48.34
M.R.S	1.36	1.82	3.11	7.05	5.34	2.54

Table 3. Analysis of variance *p*-values and variance ratios for maturity, ripeness, and storage effects on the non-structural carbohydrate composition of ‘Hass’ avocado fruit skin. Fruits from three harvests were assessed when unripe or ripe before or after storage for 28 days at 5 °C. Fruits were ripened at 20 °C.

Source of Variation	ANOVA <i>p</i> -Value					
	Mannoheptulose	Perseitol	Glucose	Fructose	Sucrose	Starch
Maturity (M)	<0.001	<0.001	<0.001	<0.001	<0.001	0.006
Ripeness (R)	<0.001	<0.001	<0.001	<0.001	0.319	<0.001
Storage (S)	<0.001	0.722	<0.001	0.209	0.718	<0.001
M.R	0.744	<0.001	0.913	0.021	<0.001	<0.001
M.S	0.603	0.074	0.197	0.013	0.415	0.001
R.S	<0.001	<0.001	<0.001	<0.001	0.106	<0.001
M.R.S	0.183	0.076	0.003	<0.001	0.246	0.001
Source of Variation	Variance Ratio					
	Mannoheptulose	Perseitol	Glucose	Fructose	Sucrose	Starch
Maturity (M)	7.64	35.41	41.88	31.32	8.68	5.26
Ripeness (R)	353.98	350.40	145.81	97.98	1.00	38.57
Storage (S)	12.52	0.13	15.45	1.59	0.13	34.37
M.R	0.30	8.80	0.09	4.00	7.48	8.68
M.S	0.51	2.65	1.64	4.48	0.89	6.98
R.S	28.01	39.05	46.38	52.87	2.64	32.91
M.R.S	1.72	2.63	6.27	8.51	1.42	7.11

The marked decline in both mannoheptulose and perseitol on ripening was consistent for all harvests, although the degree of decrease in unstored fruit was greater than in stored fruit. This suggests that there is not an absolute value for tissue concentrations in ripe fruit but that concentrations are possibly affected by the ripening process. The most obvious difference between stored and unstored ripe fruit was the time taken for the fruit to ripen, from on average ~12–14 days without storage (Table 1) to on average 4–5.5 days for stored fruit, with the average value decreasing with later harvest.

3.2. Fruit Glucose, Fructose, and Sucrose

Overall, the concentrations of glucose and fructose in the skin were higher than in the flesh (Figure 2A–D, Tables 2 and 3). As with mannoheptulose and perseitol, the

concentrations of glucose and fructose in the flesh and skin reduced with maturation and ripening. The concentrations in the ripe fruit were dependent on whether the fruit had been stored or not, with higher concentrations in the fruits ripened after storage than in those fruits ripened immediately after harvest. The effect of storage was less clear, being affected by the interaction with maturity in the flesh, but not in the skin.

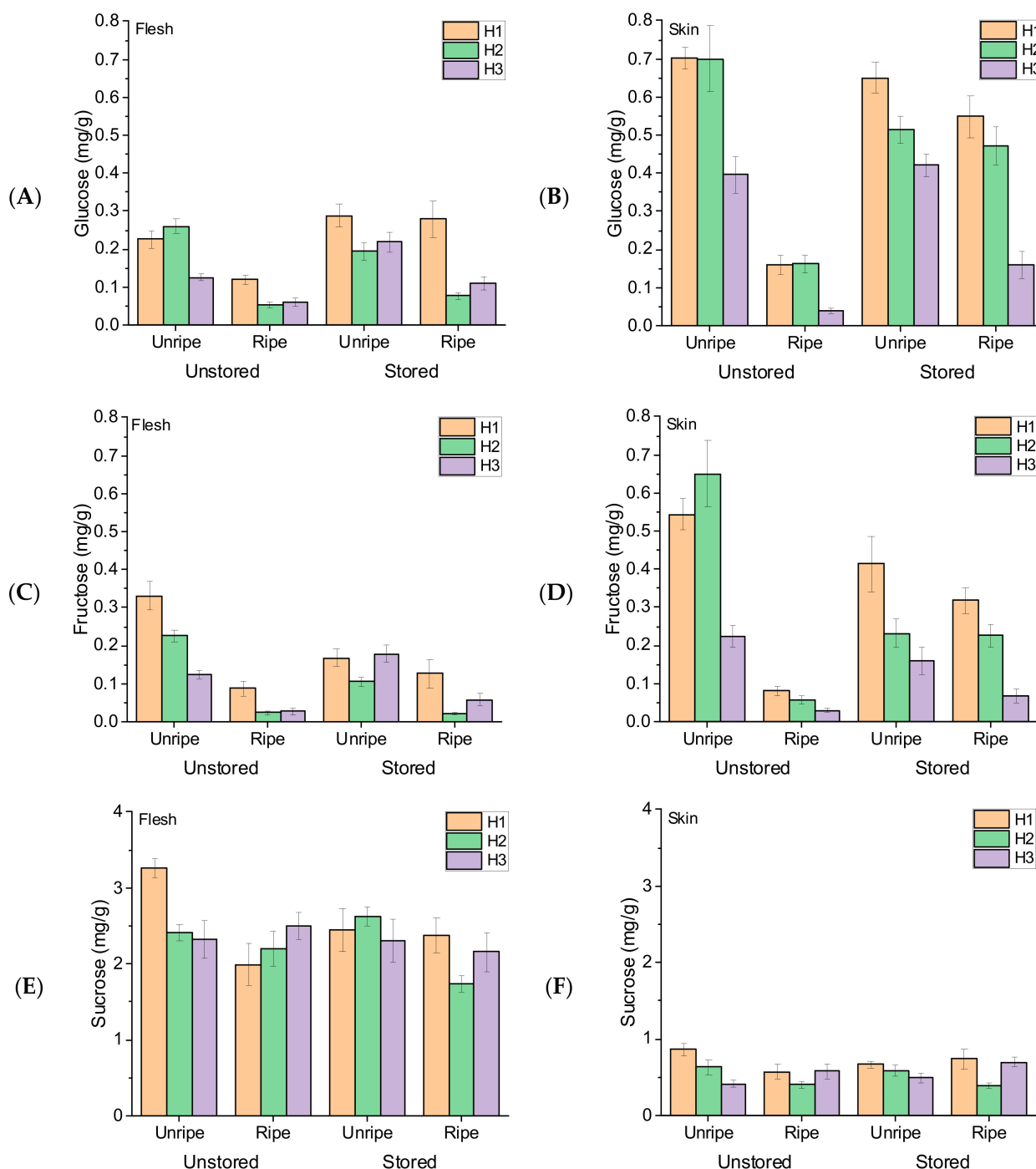


Figure 2. Glucose (A,B), fructose (C,D), and sucrose (E,F) in the flesh (A,C,E) and skin (B,D,F) of 'Hass' avocado fruit from three harvests (H1–H3) sampled when unripe or ripe before (Unstored) or after (Stored) storage for 28 days at 5 °C. Fruits were ripened at 20 °C. Values are the means of 12 fruit $\pm$ s.e.m.

The overall concentration of sucrose was ~3x higher in the flesh than the skin, with few clear effects of maturity, storage, and ripening (Figure 2E,F).

3.3. Fruit Starch

The pattern of starch changes differed from those for the soluble 6-C and 7-C carbohydrates (Figure 3, Tables 2 and 3). There was no effect of maturity on the starch content of the fruit flesh at harvest ($p = 0.181$), but a marked decrease in the skin of the fruit from H3 compared with H1 and H2 ($p = 0.006$). There was a large decrease in starch associated with both storage and ripening in both the flesh and the skin. However, the decline in starch in the flesh of the H3 fruit on ripening immediately after harvest was comparatively slow. For both tissues, there was a significant interaction effect between storage and ripening (Tables 2 and 3). The decrease in starch during storage meant that there was little starch remaining to be lost on subsequent ripening.

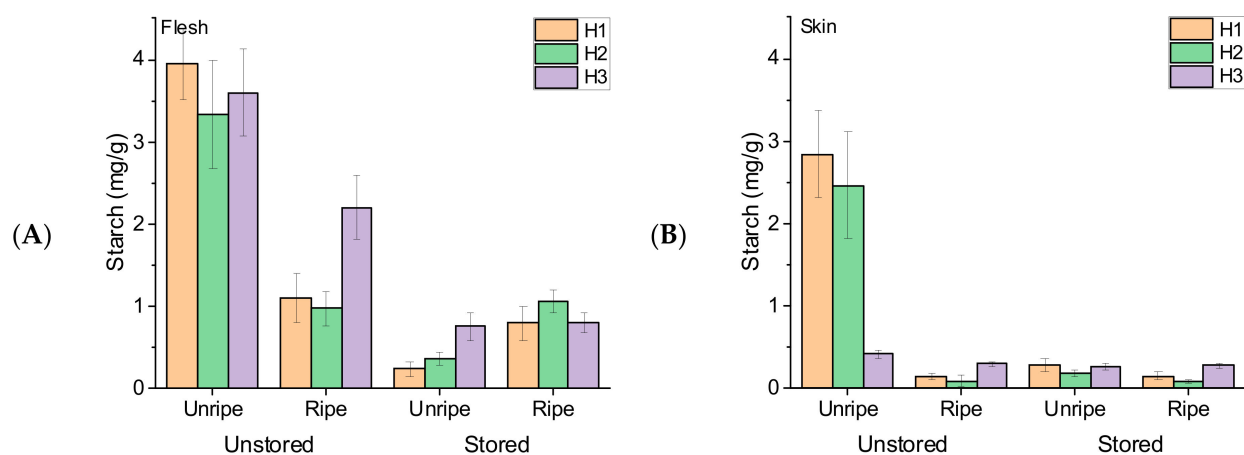


Figure 3. Starch in the flesh (A) and skin (B) of ‘Hass’ avocado fruit from three harvests (H1–H3) sampled when unripe or ripe before (Unstored) or after (Stored) storage for 28 days at 5 °C. Fruits were ripened at 20 °C. Values are the means of 12 fruit $\pm$ s.e.m.

3.4. Tree-to-Tree Variability

While the project was not designed to investigate tree-to-tree variability in detail, by maintaining the fruit identities throughout storage and ripening, it has been possible to see changes among the fruits from the different trees across harvests. The average at-harvest unripe fruit data shown in Figures 1–3 have been investigated further in terms of the tree from which the fruit came. Within the overall trends already described, differences among the individual trees are apparent (Figures 4–6). The most obvious tree differences were the lower mannoheptulose in the flesh of the fruit from Tree 2 at H2 and in the skin of the fruit from the same tree at H2 and H3 (Figure 4). For the soluble 6-C carbohydrates, there were, likewise, lower concentrations in the fruit from Tree 2 at H2 and possibly also at H1 (Figure 5). The skin glucose and fructose concentrations were markedly lower in the fruit from Tree 2 at H2, albeit with a large fruit-to-fruit variability (Figure 5). In contrast to the lower soluble carbohydrates in the fruit from Tree 2 at H2 described above, there was more starch in both the flesh and the skin of these fruits than in the fruits from the other trees (Figure 6).

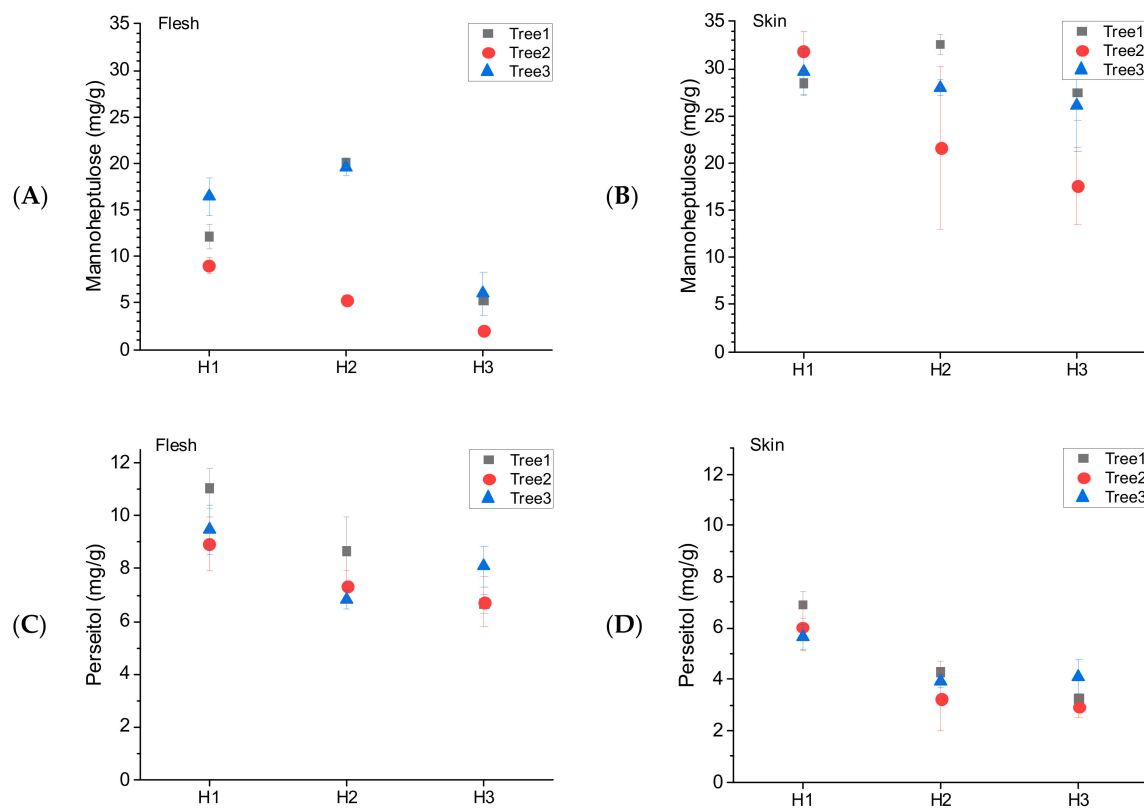


Figure 4. At-harvest mannoheptulose (A,B) and perseitol (C,D) content of the flesh (A,C) and skin (B,D) of ‘Hass’ avocado fruit. Fruits were harvested three times (H1–H3) from three trees. Values are the means of four fruit $\pm$ s.e.m.

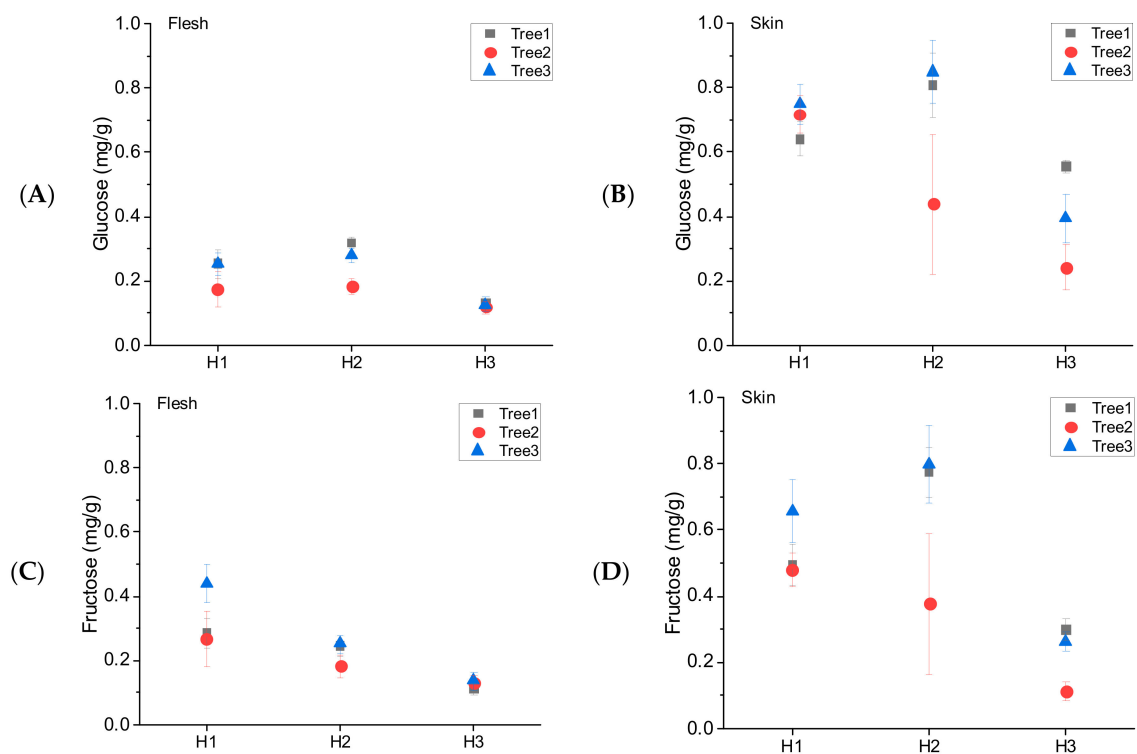


Figure 5. Cont.

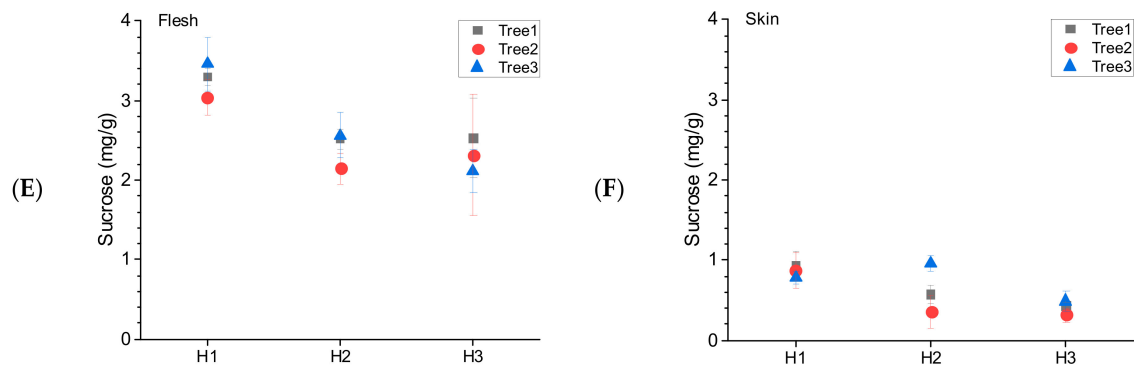


Figure 5. At-harvest glucose (A,B), fructose (C,D), and sucrose (E,F) content of the flesh (A,C,E) and skin (B,D,F) of 'Hass' avocado fruit. Fruits were harvested three times (H1–H3) from three trees. Values are the means of four fruit $\pm$ s.e.m.

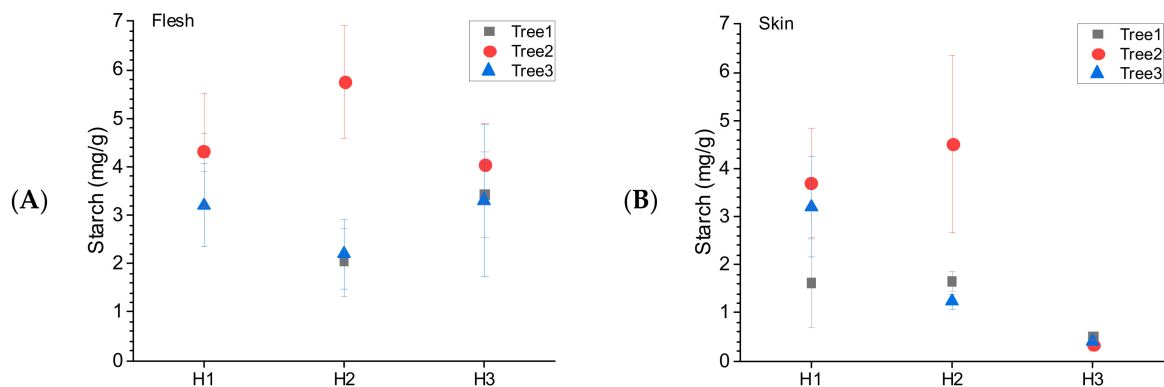


Figure 6. At-harvest starch content of the flesh (A) and skin (B) of 'Hass' avocado fruit. Fruits were harvested three times (H1–H3) from three trees. Values are the means of four fruit $\pm$ s.e.m.

4. Discussion

Significantly decreased concentrations of mannoheptulose and perseitol were observed with the maturation and ripening of 'Hass' avocado fruit but less so with storage. Similar changes were observed in glucose and fructose, but not in sucrose, content. Starch concentration in the flesh was not affected by maturity but reduced on ripening immediately after harvest or with storage. There was no further decline in starch upon ripening after storage. In contrast to the flesh, there was a major decline in the skin's starch concentration with maturity, as well as with ripening and storage.

Clearly, the changes in concentrations of non-structural carbohydrates with storage and ripening are against a changing background with maturity. Hence, the degree of change possible after storage or ripening may depend on the starting concentration, which will depend on the fruit maturity.

These findings concur with previous reports of a decline in mannoheptulose with fruit maturation [5,25]. This is particularly relevant in New Zealand, where fruits are harvested commercially over a wide period, from ~9–14 months after flowering, as dry matter (oil content) increases from ~24%–>35%. Fruits in New Zealand are relatively slow to fill with oil and are held on the tree for longer than is the case for many commercial producers in other countries to meet marketing requirements.

A further element to consider is the lack of consistency in the carbohydrate concentrations of the ripe fruit. For both mannoheptulose and perseitol, in both the flesh and the skin, the concentrations in ripe fruit after storage were higher than in fruit allowed to ripen immediately after harvest. This suggests that the final concentration is not defined by the fruit ripeness (texture) alone. A possible explanation is the difference in ripening time; the fruit ripened without storage took considerably longer to ripen than stored fruit, on

average 11.8–13.9 d and 4.0–5.5 d, respectively. Declines in both hexose and heptose sugars have previously been associated with the high respiratory activity of avocado fruit, both in the pre-climacteric and climacteric states [5]. Differences in the availability of respiratory substrates may affect the size of the respiratory climacteric, as sometimes seen among individual fruit.

The changes in glucose, fructose, sucrose, and starch with maturity have received less attention. A recent suggestion has been to use total soluble solids for maturation monitoring and ripening prediction [15,16] or, more recently, for crop estimation and orchard management [14]. However, it should not be forgotten that the dry matter harvest index is about the eating quality of the fruit and cannot be omitted if new criteria are considered unless they also evaluate this aspect of the fruit. In fact, even reports on developments for fruit maturity with avocados tend to simply review methods of dry matter measurement [26]. The ability to predict ripening from total soluble solids will depend on whether samples are taken before or after storage, with changes in soluble carbohydrates with both maturation and storage making the total soluble solids variable as a starting point.

Initial attempts have been made to associate the fruit's carbohydrate status with the tree phenology [1,2,25]. In addition, the changing carbohydrates and tree phenology were assessed relative to ripe fruit quality [25]. However, there was little association between carbohydrate content and fruit quality (including stem-end rots, body rots, and vascular browning). Only with diffuse flesh discolouration (DFD) were there any associations with those factors that were different late in the season, when the pre-climacteric period was reduced and DFD developed in storage [25]. Perhaps of more value to understanding the loss of quality late in the harvest season due to rots [27] may be the information on the skin's carbohydrate content and, in particular, the large reduction in starch content in fruit from H3 in this trial. The fact that quality loss tends to be through rot development suggests that skin changes will be important. It should also be noted that the fruits that were harvested late (H3) were harvested in the middle of summer, when temperatures may be high and water limiting.

Beyond the environmental differences among harvests, there are significant differences in tree phenology over the period of commercial harvest [28–31]. In the Bay of Plenty, New Zealand, flowering starts in late October/early November and lasts for ~5–7 weeks. As a consequence, for fruit harvested after December, the trees are carrying both the current and the next year's crop at the same time. This is in addition to other competing aspects of tree growth, such as root growth.

The whole-tree carbohydrate cycling has long been associated with fruit production [32,33] and, in particular, the association between tree carbohydrate reserves and alternate bearing [32,34]. The presence of differences among the carbohydrate contents of fruit from trees even in the same orchard has been illustrated in the current trial. Overall, there was a difference in fruit from Tree 2 compared with those from Trees 1 and 3, with a suggestion that the decrease in flesh mannoheptulose in Tree 2 occurred earlier (H2) than in Trees 1 and 3 (H3). Likewise, for the skin of fruit from Tree 2, there was an earlier decline in glucose and fructose at H2 than at H3 for fruits from Trees 1 and 3. These lower concentrations of glucose and fructose were associated with a higher starch concentration in fruit from Tree 2 at H2. Thus, whilst the trends in fruits from the three trees were similar, the absolute amounts and times of change differed. Given the complexity of carbohydrate partitioning between vegetative and reproductive growth and the carbohydrates cycling within trees [34,35], it would be surprising if tree phenology did not have an impact on the fruit. Perhaps this also accounts for fruit from H3 tending to have an inherently longer pre-climacteric period than fruit from H1, when the common trend is for later-harvested fruit to have a shorter pre-climacteric period.

5. Conclusions

It is concluded that the non-structural carbohydrate composition of ‘Hass’ fruit is variable, with significant changes occurring associated with maturation, storage, and ripening. The compositions of flesh and skin tissues are not consistently proportionate. Maturation provides the initial baseline composition from which any further changes through storage or ripening can occur. The changes with maturation appear associated with the tree’s phenology, with tree-to-tree differences in the timing and/or degree of change. A project designed specifically to investigate the link with tree phenology appears warranted.

Author Contributions: Conceptualization: J.B. (Jeremy Burdon); funding acquisition: J.B. (Jeremy Burdon); investigation: D.B., J.B. (Judith Bowen) and H.B.; methodology: J.B. (Jeremy Burdon), D.B., J.B. (Judith Bowen) and H.B.; writing—original draft: J.B. (Jeremy Burdon); writing—review and editing: J.B. (Jeremy Burdon), D.B., J.B. (Judith Bowen) and H.B. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement: The data supporting the results of this research are included within the article.

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