

大,至成熟采收时则保持较高活性,其中 SS 的活性达到 5.00 以上。柠檬果皮和汁胞在 7 月底时 SAI 和 NI 活性较高。随着果实的发育,果皮中 SAI 活性迅速下降,在成熟采收时又迅速上升,但活性略低于 7 月底;其它 3 种酶活性有一定的起伏变化,但在采收时活性都较低。柠檬汁胞中只有 NI 随着果实发育而活性下降,在成熟采收时,SAI 则表现出较高的酶活性,NI、SS 和 SPS 活性较低。

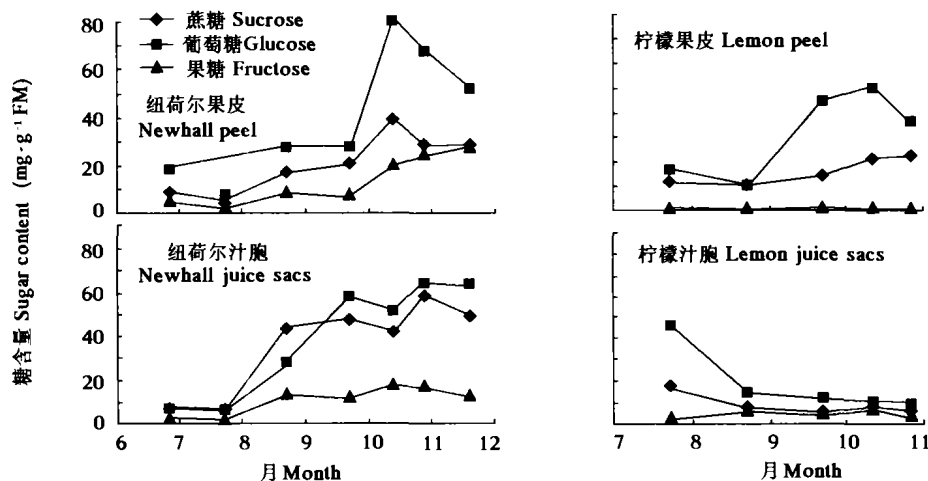


图 1 柑橘果实中糖含量的变化

Fig. 1 Changes of sugar contents during the development of citrus fruits

通过对同一品种不同部位各种酶活性进行独立样本平均值 t 检测发现,脐橙果皮和汁胞中的 SPS 活性差异明显,SS 活性差异接近显著水平;柠檬汁胞和果皮中各酶活性平均数差异均未达到显著水平。比较脐橙和柠檬对应部位各酶活性差异可以发现,在成熟采收时,脐橙果皮中 NI 活性最高,而柠檬果皮中是 SAI 活性最高,且比脐橙果皮中高约 3 个酶活力单位;汁胞中,脐橙中 SAI 活性极低,SS 活性最高,柠檬则是 SAI 活性最高,其它 3 种酶活性较低(图 2)。

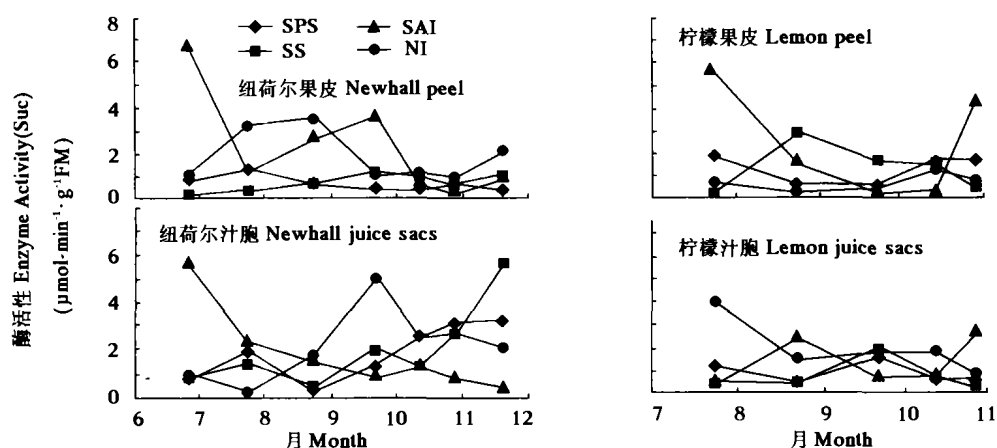


图 2 柑橘果实中相关酶活性的变化

Fig. 2 Changes of enzyme activities during the development of citrus fruits

Lowell 等^[4]认为 SPS 和 NI 在柑橘果实汁胞中表现最为活跃。Hubbard 等^[5]认为蔗糖的积累需要 SAI 活性的下降为前提,但是认为 SAI 活性下降是果实成熟的正常功能,而不是决定蔗糖积累的主因。Zhu 等^[6]认为存在一个 SAI 活性阈值,当 SAI 活性超过阈值时,蔗糖就不会积累。Ohyama 等^[7]、Klann 等^[8]用酸性转化酶(SAI)的 cDNA 分别转入马铃薯和番茄植株中,发现反义基因有效抑制了成熟植株中 SAI 的活性,蔗糖显著积累,己糖减少。本研究表明,随着脐橙汁胞中糖分的积累,SAI 活性持续下降,至采收时达最低值(几乎为 0),而 SPS、NI 和 SS 活性表现起伏变化,至采收时 SS 保持

了较高的活性,说明脐橙汁胞中糖组分的积累与 SAI 活性的下降有很大的关系,SS、SPS 和 NI 对脐橙汁胞中糖组分的调节作用也不可忽视^[2~8]。本试验发现,随着柠檬果实成熟,NI 活性下降,成熟时 SAI 活性则较高,是其它酶的 6 倍以上,说明果实成熟前柠檬汁胞中糖分的利用与 NI 活性极大关系,在成熟期则与高 SAI 活性、低 SPS 和 SS 活性有关。另外,脐橙和柠檬汁胞中糖组分差异明显,比较对应部位各相关酶的活性变化动态,说明 SS 和转化酶(SAI、NI)在柑橘果实汁胞糖代谢中起到重要作用。

本研究发现:脐橙果皮 SPS 和 SS 活性维持在较低水平上,而 SAI 和 NI 活性大小交替变化,起着交替降解蔗糖的作用。柠檬果皮中 NI 和 SAI 活性类似,SS 活性则在多数时期保持较高水平。

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Sugar Accumulation and Changes of Sucrose-metabolizing Enzyme Activities in Citrus Fruit

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Abstract: Sugar contents and activities of sugar-metabolizing enzymes in the peel and juice sacs were analyzed during the fruit development of Newhall orange (*Citrus sinensis* Osb.) and Eureka lemon (*C. limon* Burm. f.). The results showed that, 1) changes of the sugar contents and activities of sugar-metabolizing enzymes were different in citrus cultivars and in different fruit parts; 2) the reduction sugar content was higher than the sucrose content in both peel and juice sacs of orange or lemon, as was different from other's study; 3) the continuous decrease of the soluble acid invertase (SAI) activity during sugar accumulation of orange juice sacs, close to zero at the fruit-harvesting time, implicated that the decline of SAI activity was likely related to sugar accumulation; and 4) the phenomena that the activity of the alkaline invertase (NI) in lemon juice sacs decreased continuously with fruit ripeness and kept the lowest level at the fruit-harvesting time while as the activity of SAI reached a higher level, up to 6 times of that of the other enzymes, indicated that the consumption of sugars in lemon juice sacs was related to NI activities during the fruit developmental stages and to SAI at fruit maturing period. Sucrose synthase (SS) and invertase might play a role in sucrose metabolism in citrus fruit juice sacs considering the significant difference of sugar contents between in orange and lemon juice sacs as well as the changes of their related sucrose-metabolizing enzymes.

Key words: Citrus; Fruit; Sugar; Sucrose-metabolizing enzyme