Biosynthesis of Fatty Acids in Higher Plants

Ringkasan

Proses fotosintesis dibincangkan secara ringkas. Fotosintesis bermula dengan pengikatan karbon dioksida di dalam suatu organel, dikenali sebagai kloroplas, yang terdapat di dalam daun. Melalui kitaran Calvin, sukros iaitu hasil primer fotosintesis dibentuk. Penjelasan yang sama bagi biosintesis lipid dalam buah kelapa sawit juga dihuraikan.

Introduction

A brief pathway of photosynthesis was discussed. Photosynthesis is initiated by fixation of carbon dioxide in an organelle called the chloroplast found in leaves, and through the Calvin cycle leads to the formation of sucrose, the primary product of photosynthesis. Sucrose is then transferred to seeds that store a large amount of starch or transferred to high lipids containing seeds such as soyabean where sucrose undergoes further reactions to form lipids. When germination takes place in high lipid seeds, the lipid is mobilised and through the glyoxylate cycle and gluconeogenic enzymes is converted back to sucrose to provide energy and carbon compounds for the growing tissues (see *Figure 1* for details of the source-sink relationship).

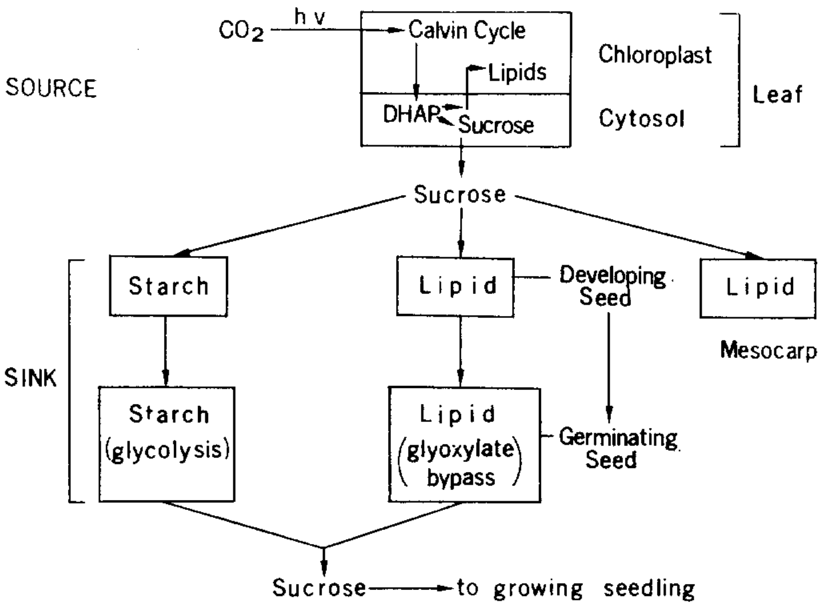

Fig. 1. Interacting Compartments in Plants

A similar explanation of lipids biosynthesis in oil palm fruits was outlined. It also has been generalised that sucrose is found in the leaf and transferred to the mesocarp of oil palm fruits and there converted to fatty acids. These fatty acids accumulate in the mesocarp and are not translocated to any other part of the plant.

Biosynthesis of Fatty Acids (Basic Biochemistry)

Fatty acids biosynthesis involves a series of reactions. The first step is the condensation of Acetyl-S-ACP and Malonyl-S-ACP to form Acetoacetyl-S-ACP accompanied by a decarboxylation. The acetoacetyl-S-ACP will undergo a series of reduction and dehydrations followed by successive chain elongation through condensation of the developing fatty acid with additional molecules of Malonyl-S-CoA and eventually C_{18} fatty acids are formed *(Table 1)*. In the leaf, all these reactions occur in the chloroplast; in the high lipid containing seeds, these reactions occur in the proplastid.

Table 1. General Reaction in Fatty Acid Synthesis

1	$CH_3COSCoA + ACP{\cdot}SH \xrightleftharpoons{\text{acetyl transferase}} CH_3CO{\cdot}S{\cdot}ACP + CoASH$
2	$HO_2C{\cdot}CH_2COSCoA + ACP{\cdot}SH \xrightleftharpoons{\text{malonyl transferase}} HO_2C{\cdot}CH_2CO{\cdot}S{\cdot}ACP + CoASH$
3	$CH_3COS{\cdot}ACP + HO_2C{\cdot}CH_2CO{\cdot}S{\cdot}ACP \xrightleftharpoons{\beta\text{-ketoacyl ACP synthase}} CH_3COCH_2CO{\cdot}S{\cdot}ACP + ACP{\cdot}SH + CO_2$
4	$CH_3COCH_2CO{\cdot}S{\cdot}ACP + NADPH + H^+ \xrightleftharpoons{\beta\text{-ketoacyl ACP reductase}} D\text{-}CH_3CH(OH)CH_2CO{\cdot}S{\cdot}ACP + NADP^+$
5	$CH_3CH(OH){\cdot}CH_2CO{\cdot}S{\cdot}ACP \xrightleftharpoons{\beta\text{-hydroxyacyl ACP dehydratase}} CH_3CH^t = CHCO{\cdot}S{\cdot}ACP + H_2O$
6	$CH_3CH = CHCO{\cdot}S{\cdot}ACP + NADPH + H^+ \xrightleftharpoons{\text{enoyl ACP reductase}} \underset{\text{butyryl ACP}}{CH_3CH_2CH_2CO{\cdot}S{\cdot}ACP} + NADP^+$
7	Butyroyl·S·ACP now reacts with a second molecule of malonyl·S·ACP and proceeds through reactions 3-6 to form hexanoyl·S·ACP, etc. until palmitoyl·S·ACP is formed.

The possible pathway of fatty acid synthesis in oil palm fruits also has been discussed briefly. Carbon dioxide enters the leaf cells of oil palm fronds. In the chloroplast, through the Calvin cycle, the carbon dioxide is converted via a series of compounds to Dihydroxyacetone phosphate (DHAP) which is then transferred to the cytosolic compartment in the leaf cell and converted to pyruvic acid. Pyruvate eventually enters the mitochondria where pyruvate is oxidised to Acetyl-CoA. This compound may then enter the Tricarboxylic Acid Cycle (Kreb's Cycle) or be hydrolysed by a specific hydrolase to form free acetate. Free acetate then diffuses out of the mitochondrion to the chloroplast to be converted to Acetyl-CoA and localised specifically in the chloroplast. Through a series of specific enzymic reaction between Acetyl-CoA and Malonyl-CoA palmitic acid is formed. Through an elongation and desaturation process oleic acid is finally formed. This acid will remain in the chloroplast until it is hydrolysed to free acid. The free acid will move out from chloroplast into "Cytosol" and remain there and not be translocated elsewhere but may be further modified (see *Figure 2*).

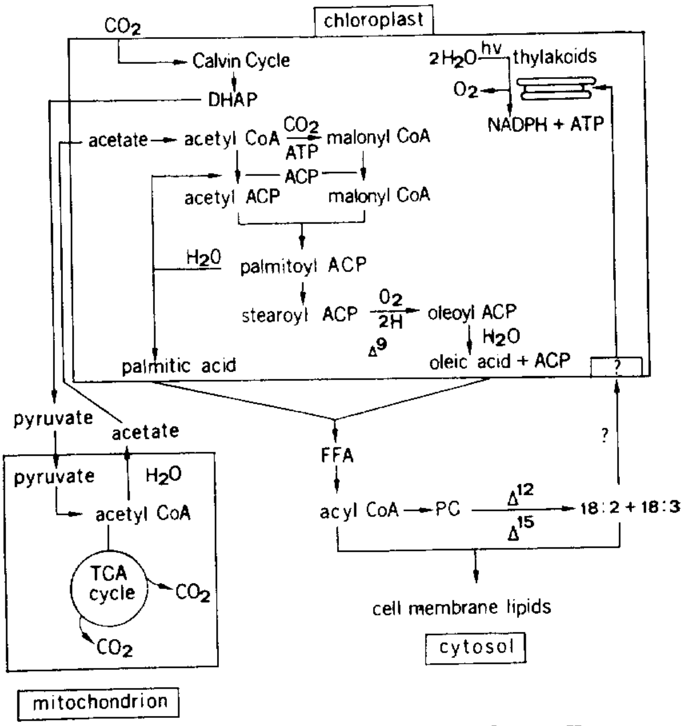

Fig. 2. Interaction of Leaf Cell Organelles

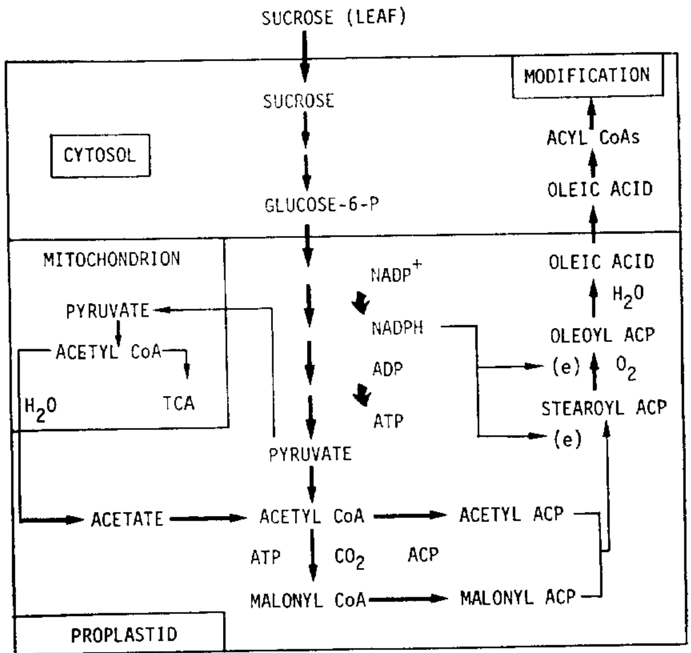

Fig. 3. Interaction of Seed Organelles for Lipid Biosynthesis
(According to Dennis, Yamada, Kerwick)

Sucrose formed in the leaf cell via DHAP is translocated by the vascular system to the developing mesocarp of the oil palm. There it is converted back to Acetyl-CoA. These reactions occur in the proplastids of the mesocarp tissue. In the proplastid all the enzymes for fatty acid synthesis occur and it is there where palmitic and oleic acids are formed. These acids are then translocated out into the cytosolic compartment and these are converted to palmitoyl and oleoyl-CoA. These very metabolically active substrates are then employed by membraneous enzymes to form the final oil droplet composed essentially of triglycerides (see *Figure 3*).

Article Credit: P. K. Stumpf.