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Recapitulation on Triacylglycerols in Plants

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Introduction

Vegetable oils, a triacylglycerol (TAG), a neutral storage lipid are abundantly found in all eukaryotes. Traditionally they have been used as a common source for edible vegetable oil and represented as a valuable source of food, fuel, and industrial raw materials. Plants accumulate TAG in distinct storage tissues, although plant vegetative tissues do not accumulate significant levels of TAG which involved in synthesis, storage, and metabolism. TAG is composed of a glycerol backbone bearing three esterified fatty acids. In plants, TAG is mainly stored as a high-energy storage compound within lipid droplets (LDs) in seeds or fruits. Vegetative tissues such as leaves and stems are typically regarded as non-lipid-storing tissues, at least under favourable environmental conditions, due to their limited contents of TAG. However, small amounts of TAG do exist in these tissues, where they have been suggested to play a role in the sequestration of toxic lipid intermediates following membrane breakdown and light-induced stomatal opening.

Vegetal oils are frequently classified in two main groups, according to their source: pulp oil from palm, olive, and avocado and seed oil from other sources. The amount of lipids in plant varies from 0.1% to 70%. Some vegetal products are fat poor that are found in 1% in lentils, 3% in mushrooms, some seeds have a middle range amount about 10% in wheat germ, 20% in soybeans while some are very oily like 44% in peanuts, 55% in almonds, 65% in walnuts. Plants store their energy production first as carbohydrates, but during ripening they transform these oxygen containing compounds in carbon-rich triglycerides. Thus, a minimum of volume is required to stock a maximum of energy content. Conversely, the triglyceride stock is reconverted into carbohydrates during germination along with an incorporation of high amount of water. One gram of oil is converted into 2.7 g of carbohydrates.

Scope of vegetable oil

In developing countries, there are numerous forms of renewable and imposition of sustainable energy has increased, because of the change in climatic condition and reduction in fuel thus exaggerated fossil fuel cost. Biomass is contributing about 70–80% of the

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global bioenergy demand because it is utilized as number one energy resource. India has the potential to resolve this energy demand due to the vast availability of biomass resources and wasteland to support cultivation of bioenergy crops. Every plant is considered as a green factory that produces millions of compounds by using solar energy and CO_2. Our potential to increase production of food and renewable resources for the growing population is restricted because of narrow knowledge in understanding the plant lipid metabolism and its function. Plant oils are dominantly having a variety of uses besides edible applications which are denoted as a non-polluting renewable resource. Besides being edible, they are now used in industrial applications such as paints, lubricants, soaps, biofuels etc. and some fatty acids are known to have anticancer potential. Importance of role of fats and fatty acids in human nutrition is gaining attention as more and more research is being done. The plants rich in fatty acids play a crucial role in human nutrition and also animal nutrition. Lipids are frequently used in ruminant meals to increase their energy supply but the supply is limited in India. Thus an ever expanding market exists for oil production from both nutritional and industrial perspectives.

Status of vegetable oil production in India

Global oilseed production had reached a record of 319 million metric tons in 2001. Part of the total production of each oilseed is used directly as food, but most is crushed to extract oil. In average, all the seeds crushed gave oil in about 26% yield. The global vegetable oil consumption has more than doubled between 1980 and 2000, reaching about 76 million tons. India produced about 10.65 million tonnes of edible oils in 2019-20, less than half of the roughly 24 million tonnes it consumed during that period, according to trade and government estimates.It imported the rest, buying around 7.2 million tonnes of palm oil from Indonesia and Malaysia, about 3.4 million tonnes of soyoil from Brazil and Argentina, and 2.5 million tonnes of sunflower oil, mainly from Russia and Ukraine.

Accumulation of TAG in plants

Triacylglycerol droplets accumulate in the outer leaflet of the ER and eventually 'bud off' from the ER to form oil bodies ranging from 0.5 to 2.5 micrometers in diameter which are surrounded by a monolayer of phospholipid, with amphiphilic oil body proteins embedded in the triacylglycerol and phospholipid layer. Although triacylglycerol accumulates to high levels in the seeds and fruits of oleaginous plants, triacylglycerol is also known to collect in other plant parts including pollen and vegetative tissue. Accumulation of triglycerides may also occur in certain yeasts and moulds. The analysis of the distribution of the fatty acyl groups in triglycerides indicates that these microbial lipids are similar to their plant. There are a very few examples of alternative forms of storage lipid in higher plants. Storage lipids may be accumulated in one or both of the main types of seed tissue, embryo or endosperm. In oilseeds embryo and in castor bean, coriander or carrot the endosperm is the major sites of lipid accumulation. But in tobacco, both embryo and endosperm tissues store lipids. Triacylglycerol is believed to be the predominant store of carbon in the majority of seed species and can account for more than 60% of the weight of the seed. It is an extremely compact energy store. The mobilisation of triacylglycerol in seed tissues requires a complex metabolic programme that is activated following germination and enables the net conversion of oil to sugars. This capacity is not present in mammals, which lack a key linking pathway called the glyoxylate cycle.

Biosynthesis of TAG in plants

Triacylglycerols are present as storage lipids in fungi and yeasts, but not in bacteria. The biosynthetic pathway involved in the synthesis of triacylglycerol. Glycerol and fatty acyl-CoA are precursors for the synthesis of triacylglycerol. Glycerol is first converted into glycerol-3-phosphate by the action of glycerokinase, followed by transfer of acyl group from acyl-CoA resulting in the formation of phosphatidic acid that involves the enzyme glycerol phosphate acyl transferase. The phosphate from phosphatidic acid is removed by the action of the enzyme phosphatidic acid phosphatase to form diacylglycerol. The final product triacylglycerol is formed by transfer of a third molecule of acyl group catalyzed by the enzyme diacylglycerol acyl transferase.

TAG Metabolism

Under conditions of lipid overload, excess fatty acids are converted into biologically inert neutral lipids in the form of TAG packaged in LDs, thereby sequestering them away from cellular membranes. Cells deficient in TAG synthesis show increased levels of membrane lipids and accumulate toxic lipid intermediates such as DAG and free FAs. They also exhibit massive proliferation of intracellular membranes and ultimately undergo programmed cell death. TAG metabolism encompasses multiple subcellular organelles, which necessitates extensive trafficking of FAs and other intermediates between cellular

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organelles and within and across biological membranes. Special cellular mechanisms appear to exist that strictly limit the buildup of toxic FAs in the cytosol during FA trafficking.

Functions of Triacylglycerol in plants

Germination and early seedling establishment

TAGs are oilseeds' main carbon storage, providing necessary energy to power early growth till seedling development. TAGs sequestered in lipid droplets are digested by TAG lipases before germination, releasing FAs, which are then transported into glyoxysomes and processed by oxidation to create acetyl-CoA. Germination is made from this ubiquitous metabolite.

Cell division and expansion

Cell division and post-mitotic expansion are essential for seedling growth. A decrease in the number of leaf cells is frequently compensated for by cell enlargement. Sucrose production from storage TAGs affects these complicated relationships between cell division and growth. TAG to sugar conversion is important not only for seedling establishment, but also for post-germinative organ development.

Stomatal opening

Stomata are pores in the epidermis of leaves lined by two guard cells through which terrestrial plants exchange gases while losing water vapour. As a result, guard cells have an impact on two important physiological processes: photosynthesis and transpiration. Many plant guard cells include lipid droplets. In general, during light-induced stomatal opening, TAG breakdown followed by oxidation of FAs is a major source of ATP, a mechanism that is evolutionary conserved from basal plant lineages through angiosperms.

Flower development

TAGs accumulate in flower petals, tapetum cells of anthers, pollen grains, and moist stigmata during flower development. TAGs have long been thought to be an energy source in flowering tissues. However, TAGs and lipid droplets are required for protein transport and pollen tube penetration in flower tissues.

TAGs in stress response

Leaf TAGs can be found in cytosolic lipid droplets (LD) and plastoglobules (PG) within plastids (top, a) (botton, b). On the right, bigger cartoons of PG and LD are displayed. (a) Lipids in the chloroplast membrane, such as monogalactosyldiacylglycerol (MGDG), are changed to diacylglycerol (DAG) and transacylglycerol (TAG) during senescence. Not only are cytosolic LDs involved in membrane lipid modification, but they also produce oxylipin during defence responses. Peroxygenase (CLO), lipoxygenase (LOX), and -dioxygenase1 (-DOX) are activated to create defence chemicals when plants are exposed to biotic stress. Membrane lipids such as phosphatidylcholines (PC) are transformed to TAGs in the ER in response to abiotic stressors.

Conclusion

Plant oil accumulation can now be manipulated thanks to our growing understanding of TAG metabolism and advances in molecular breeding methods. However, whether increasing oil content in storage or vegetative tissues can contribute to physiological role and stress tolerance in crop species has yet to be identified. To acquire a complete understanding of the situation, a systemic examination of the performance of such crops and cropping systems, as well as the fatty acid compositions of their vegetative tissues, would be required. Furthermore, knowing genes encoding LD-associated proteins may be necessary in the future for the development of high oil and stress-tolerant cultivars.

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