In planta novel starch synthesis

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1. Introduction

Starch is the most abundant reserve carbohydrate present in higher plants, where it is predominantly found in the amyloplasts of storage organs such as roots, tubers and seeds. The green leaves have the unique ability to harvest light energy in the presence of carbon dioxide and water to synthesize carbohydrates, which are converted into starch. Starch present in the leaves is known as transitory starch, because it is broken down into simple sugars, which are transported to storage organs such as roots, tubers or seeds, where storage starch is synthesized for utilization by the plants at a later stage. Approximately 2050 and 679 million tonnes of storage starch is produced annually by the cereal and tuber crops, respectively, (Tester and Karkalas 2002) and harvested by humans for food, feed and industrial applications.

Starch is a staple in the diet of the world’s population. Almost fifty percent of the calories in human diet are supplied by starch based products. In the tropics, the indigenous starch crops of the tropics, cassava, sorghum, millet or yam, are considered wonders of nature, because with the sun and rain, and little or no artificial inputs, they are able to grow in great abundance. For centuries, tropical starches have served as staple food for millions of people, throughout the hot and humid regions of the world. These starch crops are so proficient to supplying essential calories to even the...
very poorest people of the world that they are considered to be the quintessential subsistence crop.

In the developed countries, starch is also used in the food and beverage industries as a thickener and a sweetener, in a multitude of processed food products. Starch is one of the most preferred industrial raw materials and it is being used to produce hundreds of products for use in several industries such as paper and pulp, textiles, cosmetics, pharmaceutical, biodegradable plastic film, construction and mining. However, for industrial applications, native starches have to be chemically modified to confer the desired physical and chemical attributes (Ellis et al. 1998). The use of starch for industrial purposes will only become economically viable when its use as a raw material can compete with petroleum-based products. The renewable and biodegradable nature of starch makes it increasingly attractive in response to the environmental concerns about the industrial wastes generated from petroleum products and the growing awareness of the potential deleterious consequences of greenhouse gas emissions from these activities. However, if starch can be modified in planta to confer some of the desirable traits, which will reduce post-harvest processing and modification, the utility of starch as an industrial raw material will be significantly enhanced. Therefore, in the late twentieth century it was emphasized that the focus of starch production will shift from low value bulk starch to high value specialty starches (Stroh 1997). The non-food uses of starch are also a prime indicator of a country’s economic condition. During periods of reduced economic growth, the volume of starch going into non-food use also drops considerably. On the other hand, during periods of rapid growth, the demand for construction materials for building industrial plants and housing, paper for packaging and wrapping various products, place a high demand on industrial raw materials (Jobling 2004).

The demand for industrial starches is increasing, but four major crops, potatoes, maize, wheat and tapioca supply most of the requirements for non-food industrial applications. Starch properties differ between the plant sources, but for specialized applications, the native starches are chemically modified. Therefore, it is advantageous to produce novel or tailor-made specialty starches in planta as it would decrease the currently imperative post-harvest modification, some of which are environmentally damaging (Slattery et al. 2000). Recent progress in the understanding of starch structure and biosynthesis and the development of molecular biology strategies to alter cellular metabolism has provided an opportunity to change starch structure in planta. In this chapter, we will discuss the storage starch structure, biosynthesis and strategies for its genetic modification for food, feed and industrial uses.