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Banana starch: production, physicochemical properties, and digestibility—a review☆

Pingyi Zhang, Roy L. Whistler, James N. BeMiller, Bruce R. Hamaker*

Whistler Center for Carbohydrate Research and Department of Food Science, Purdue University, West Lafayette IN 47907-2009, USA

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Abstract

The large quantity of green cull bananas has the potential of being used industrially and, thereby, to improve banana economics and eliminate the large environmental problem presented by banana waste. This review summarizes the present knowledge of the composition, structure, physiochemical properties, modifications, and digestibility of banana starches and provides suggestions for needed research to improve the utilization of green cull bananas.

Keywords: Banana; Starch; Structure; Physicochemical properties; Modifications; Digestibility

1. Introduction

Banana is a general term embracing a number of species or hybrids in the genus *Musa* of the family Musaceae. Almost all of the known edible-fruited cultivars arose from two diploid species, *Musa acuminata* and *Musa balbisiana*, which are native to southeast Asia. There are diploid, triploid and tetraploid hybrids composing subspecies of *M. acuminata*, and between *M. acuminata* and *M. balbisiana* (Robinson, 1996; Stover & Simmonds, 1987). Conventionally, the haploid contributions of the respective species to the cultivars are noted with the letters A and B. Cavendish subgroup banana cultivars (*M. cavendishii*), which are the mainstays of the export trades are pure triploid *acuminata* (AAA group). The two Linnaean epithets, *M. paradisiaca* and *M. sapientum*, are members of the AAB group (Stover & Simmonds, 1987). Plantains are generally the larger, more angular starchy fruits of hybrid triploid cultivars in the banana family intended for cooking, but also edible raw when fully ripe (Robinson, 1996).

Bananas are produced in large quantities in tropical and subtropical areas. World production of *Musa* in 2003 was estimated at 102 million MT of which about 68% was classified as bananas and 32% as plantains (FAO, 2003). The crop is of major importance to the people in the growing areas as it forms a major portion of the annual income and a source of food. As is the case for most tropical products, due to the special climatic conditions needed to grow bananas, they are mainly produced in developing countries. Developed countries are the usual destination for export bananas. Production, as well as exports and imports of bananas, are highly concentrated in a few countries. Ten major banana-producing countries accounted for about 75% of total production in 2003 with India, Ecuador, Brazil, and China accounting for half of the total (Table 1). Latin America and the Caribbean islands supplied more than 80% of world total exports (ca. 15 million MT), with the four leading banana exporter countries (Ecuador, Costa Rica, Philippines and Colombia) accounting for about two-thirds of world exports (FAO, 2003).

About one-fifth of all bananas harvested become culls. When banana bunches arrive at central collection stations, bananas too small for shipping are removed, along with those that have damaged or spoiled areas that could cause microbial contamination of the bunch. Rejected bananas are normally disposed of improperly. Attempts are made to use

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* Corresponding author. Address: Department of Food Science, Purdue University, Food Science Building, West Lafayette, IN 47907-2009, USA. Fax: +1 765 494 7953.

E-mail address: hamakerb@purdue.edu (B.R. Hamaker).

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Table 1
World production statistics of banana and plantain in 2003 (Source: FAO, 2003)

Country	Production (×1000 MT)	Country	Production (×1000 MT)
Asia	37,140	Central America and Caribbean	8519
India	16,450	Mexico	2027
China	5827	Costa Rica	1863
Philippines	5500	Guatemala	1000
Indonesia	4312	Honduras	965
Thailand	1800	South America	15,152
Viet Nam	1220	Brazil	6518
Bangladesh	654	Ecuador	5609
Africa	6813	Colombia	1450
Burundi	1600	Europe	441
Egypt	850	Spain	405
Cameroon	689	Oceania	1174
Uganda	615	Papua New Guinea	870
		Total banana	69,286
Africa	23,308	South America	6362
Uganda	10,000	Colombia	2925
Rwanda	2408	Peru	1600
Ghana	2300	Ecuador	860
Nigeria	2110	Venezuela	760
Côte d'Ivoire	1420	Central America and Caribbean	2261
Congo	1250	Cuba	797
Cameroon	1200	Asia	1040
Kenya	830	Sri Lanka	610
		Total plantain	32,974

these culled bananas in animal feed and products such as chips, flakes and powders, but they are used only to a limited extent for these purposes due to the low value of such products. Therefore, in countries such as Costa Rica, dumping of the rejected bananas into rivers is a common practice. The high carbohydrate content of the crop creates high biochemical oxygen demand (BOD) in the rivers and, hence, reduces aquatic animal populations.

A successful industrial use of the culled bananas would alleviate the problem while offering employment and financial return to the inhabitants. Most likely, the first practical application of culled bananas would be use of the pulp for starch production or production of a low-cost banana flour ingredient. Banana starch has the potential to be a commodity starch because of its specific properties and its potential production from low-cost, cull bananas. Green banana pulp contains up to 70–80% starch on a dry weight basis, a percentage comparable to that in the endosperm of corn grain and the pulp of white potato.

Native raw banana starch is known to be resistant to the attack of α-amylase and glucoamylase, with in vivo results showing that 75–84% of the starch granules ingested reached the terminal ileum (Englyst & Cummings, 1986; Faisant, Buleon et al., 1995). Although it was found that the resistance was largely overcome by cooking to gelatinize the starch, other studies showed that the 'easily hydrolysable starch' fraction of cooked banana starch was as low as 47% and was comparable to the known low-digestible cooked yam starch (40%) (Cerning-Beroard & le Dividich, 1976; Lozano, Cabrera, & Salazar, 1973). While there is limited commercial use for raw starch in foods, there is substantial application for such a trait in cooked starch. The value of slowly digestible and low-glycemic-index starch is embodied in the current diet craze of 'low carb' foods.

In conclusion, banana starch has potential, both from its digestion properties and functional properties, to have application in processed foods and become a commercially viable starch product. Use of culls for production of starch would provide a starch that might be competitive in the world starch market, improve banana economics, and eliminate a large environmental problem presented by cull bananas.

2. Occurrence and transformation of banana starch

The composition of bananas changes dramatically during ripening. von Loesecke (1950) classified banana ripening into eight stages according to peel color. Starch is the principal component of green bananas, which undergoes important changes during ripening. The average starch content drops from 70 to 80% in the pre-climacteric (prior to starch breakdown) period to less than 1% at the end of the climacteric period, while sugars, mainly sucrose, accumulate to more than 10% of the fresh weight of the fruit. Total soluble sugar content can reach 16% or higher of the fruit fresh weight (about 80% water content), indicating a high rate of conversion (Cordenunsi & Lajolo, 1995). Amylases participate in starch hydrolysis, but they are probably not linked to sucrose synthesis. Starch–sucrose transformation during ripening of bananas involves several enzymes and more than one pathway. In spite of the importance of this transformation in terms of fruit physiology, little is known about the mechanisms involved.

Lii, Chang, and Young (1982) investigated changes during ripening of dessert bananas with respect to physical and chemical properties of their starch and their content of reducing sugars and sucrose (shown in Table 2). Terra, Garcia, and Lajolo (1983) followed starch, sucrose, glucose, and fructose concentrations and activity of some enzymes of sucrose synthesis during ripening of pre-climacteric (prior to starch breakdown) bananas (*M. acuminata*). As starch was degraded, sucrose content increased and preceded accumulation of glucose and fructose. UDP–glucose pyrophosphorylase activity remained constant, while the activity of sucrose synthase and invertase increased. The observed sugar and enzyme changes indicated that starch to sucrose transformation via glucose 1-phosphate