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Factors affecting the digestibility of raw and gelatinized potato starches

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Abstract

The enzymatic digestibilities of raw and gelatinized starches in various potato starches, as well as sweet potato, cassava, and yam starches, were estimated, along with other starch properties, such as the phosphorus content, median granule size, and rapid visco analyzer (RVA) pasting properties. Furthermore, correlation coefficients were calculated between the hydrolysis rates (HR) by amylase and other starch quality parameters. A larger granule size was closely associated with a lower HR in raw starch, while the HR in gelatinized starch did not correlate with the median granule size. An increase in phosphorus content resulted in a definitely lower HR in raw starch and tended to decrease the HR in gelatinized starch for the composite of potato and other starches. In contrast, no correlation coefficients of the phosphorus content with the HRs in raw and gelatinized starches were observed within potato starches. Starches with higher peak viscosity and breakdown showed a lower HR in raw starch, while few or no effects of these RVA parameters on the HR in gelatinized starch were observed for the composite of potato and other starches or among potato starches, respectively.

Keywords: Potato starch; Digestibility; Phosphorus content; Granule size; Pasting properties

1. Introduction

Starch is the major source of available energy-producing carbohydrate in the human diet. Starch that avoids hydrolysis by amylolytic enzymes in the small intestine and passes to the large bowel for fermentation is defined as resistant starch (RS) (Thompson, 2000). RS is thought to be desirable in human health, as it has functional properties similar to fermentable dietary fibres. The content of RS is related to the rate of starch digestion by amylolytic enzymes. Starch digestibility is largely ascribed to the plant source and is dependent on the physicochemical properties of the starch. Furthermore, it is also influenced by processing and storage conditions. As most starchy foods are cooked before consumption, the enzymatic digestibility of gelatinized starch is a critical property in the food industry. Additionally, raw or nearly raw starch is sometimes utilized in food processing. Therefore, estimating the digestibility of raw starch is also meaningful when making value-added food products. The potato is an important starch crop in Japan. In 2004, 38% of the total net production was utilized for starch production. It is generally accepted that investigation of the enzymatic digestibility of potato starches has led to their high utilization in the food industry. In potato starch, raw starch granules have a larger granule size and typical B-crystalline structure, as studied by X-ray diffraction. Tests of in vitro hydrolysis by amylolytic enzymes have indicated extremely low digestibility of raw potato starch (Englyst, Kingman, & Cummings, 1992; Fuwa, Nakajima, & Hamada, 1977; Kingman & Englyst, 1994; Sandstedt, Strahan, Ueda, & Abbot, 1962). Compared to other starches, potato starch has a manifestly higher concentration of covalently bound phosphate (Hizukuri, Tabata, & Nikuni, 1970). Starch phosphate has a large impact on the starch pasting

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characteristics. Particularly, higher phosphorus in potato starch is associated with higher peak viscosity (Noda et al., 2004a,b, 2006; Wiesenborn, Orr, Casper, & Tacke, 1994). As amylolytic enzymes are incapable of bypassing the phosphorylated glucosyl residue, phosphoryl-oligosaccharides are released from the digestion of potato starch with amylase (Abe, Takeda, & Hizukuri, 1982; Kamasaka et al., 1995; Takeda, Hizukuri, Ozono, & Suetake, 1983). It is likely that higher phosphorus content in potato starch might reduce the enzymatic digestibility of gelatinized starch, as well as raw starch. Potato starch properties, including the granule size, phosphorus content and pasting properties, differ to some extent according to cultivars and environmental factors (Noda et al., 2004a,b, 2006; Wiesenborn et al., 1994). However, experimental data on starch digestibility are not available for many types of potato starches.

The objective of this study was to assess the variation in the enzymatic digestibility of different potato starches. Isolated potato starches, which vary widely in granule size, phosphorus content and RVA pasting properties, as well as other representative tuber and root starches, were selected for the evaluation of the enzymatic digestibility of gelatinized and raw starches. Additionally, the effects of starch quality parameters, median granule size, phosphorus content and RVA pasting properties on enzymatic digestibility were determined.

2. Materials and methods

2.1. Starch samples

Details about the profiles of tuber and root starches examined in this study are given in Table 1. Fifteen potato samples, consisting of 14 cultivars, were grown at the experimental farm at the National Agricultural Research Center for the Hokkaido Region (NARCH) at Memuro, Hokkaido. Starches were isolated from these potato samples by a previously reported method (Noda et al., 2004b). Seven potato starch samples, which were derived from four cultivars and were produced by the Jinno Starch Co., Sarabetsu, Hokkaido, were purchased and also used for this experiment. Four differently sized potato starch samples, which were produced by air classification at the Nakashari Starch Factory, Shari Agricultural Cooperative Association, Shari, Hokkaido, Japan, were used in this study. Two different cultivars of sweet potato samples were grown at the experimental farm at the National Institute of Crop Science (NICS), Tsukuba, Ibaraki. Starches were isolated from these sweet potato samples using a previously described method (Noda, Takahata, Nagata, & Monma, 1992). One sweet potato starch was purchased from Haraigawa Starch Factory, Kimotsuki Agricultural Cooperative Association, Kanoya, Kagoshima, Japan. Cassava starch, isolated from cassava tubers grown in Thailand, was obtained from Nippon Starch Chemical Co., Ltd., Osaka, Japan. Yam starch was isolated from fresh yam tubers obtained from Kawanishi Agricultural Cooperative Association, Obihiro, Hokkaido, Japan, as reported previously (Zaidul, Norulaini, Omar, Yamauchi, & Noda, 2007).

Table 1
Profiles of tuber and root starches examined

No.	Botanical source	Cultivar	Year	Origin
1	Potato	Konafubuki	2005	NARCH
2	Potato	Setoyutaka	2005	NARCH
3	Potato	Shadow Queen	2005	NARCH
4	Potato	Oojiro	2005	NARCH
5	Potato	Kitamurasaki	2005	NARCH
6	Potato	Hokkaikogane	2005	NARCH
7	Potato	Benimaru	2005	NARCH
8	Potato	Nothern Ruby	2005	NARCH
9	Potato	Touya	2005	NARCH
10	Potato	Benimaru	2004	NARCH
11	Potato	May Queen	2004	NARCH
12	Potato	Touya	2004	NARCH
13	Potato	Inca-no-mezame	2004	NARCH
14	Potato	Norin No. 1	2004	NARCH
15	Potato	Toyoshiro	2004	NARCH
16	Potato	Hokkaikogane	2005	Jinno Starch Co.
17	Potato	Norin No. 1	2005	Jinno Starch Co.
18	Potato	Benimaru	2005	Jinno Starch Co.
19	Potato	Hokkaikogane	2004	Jinno Starch Co.
20	Potato	Eniwa	2004	Jinno Starch Co.
21	Potato	Norin No. 1	2004	Jinno Starch Co.
22	Potato	Benimaru	2004	Jinno Starch Co.
23	Potato	Unknown	2005	Nakashari Starch Factory
24	Potato	Unknown	2005	Nakashari Starch Factory
25	Potato	Unknown	2005	Nakashari Starch Factory
26	Potato	Unknown	2004	Nakashari Starch Factory
27	Sweet potato	Purple sweet road	2002	NICS
28	Sweet potato	Healthy red	2002	NICS
29	Sweet potato	Unknown	2004	Haraigawa Starch Factory
30	Cassava	Unknown	2005	Nippon Starch Chemical Co., Ltd.
31	Yam	Unknown	2005	Kawanishi Agricultural Cooperative Association

2.2. Starch analysis

Several starch characteristics, namely, the phosphorus content, granule size distribution, and RVA paste viscosity at 4% starch suspension, were determined, as previously reported (Noda et al., 2004b). The hydrolysis rate (HR) was determined by the modified method of Englyst et al. (1992). For the HR analysis in raw starch, starch granules (0.4 g) were weighed in 50 ml screw-cap tubes and suspended in 20 ml of a 0.1 M acetate buffer (pH5.2). Then, 5.0 ml of an enzyme solution containing 633 mg of pancreatin from porcine pancreas (P-1500, Sigma Chemical, St. Louis, MO), 2.86 mg of amyloglucosidase from Rhizopus (A-0273, Sigma Chemical, St. Louis, MO), and 2.64 mg of invertase, grade VII, from bakers' yeast (14504) were