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Changes of dietary fiber and starch composition of processed potato products during domestic cooking

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The effects of domestic cooking on dietary fiber and starch composition of selected processed potato products were evaluated. Microwave-heating and deep-fat frying reduced an appreciable amount of *in-vitro* digestible starch and significantly increased both the resistant starch (RS) and water-insoluble dietary fiber (IDF), while boiling and baking had less effect. Water-soluble dietary fiber content was not affected by any of the domestic cooking methods studied. The significant correlation between IDF and RS supported the idea that some of the starch in cooked potato had become indigestible by amylolytic enzymes, and this RS might contribute to the observed increment in the IDF fraction.

INTRODUCTION

In recent years there has been increasing interest in dietary fiber (DF), as a result of suggestions that it gives protection against diverticulosis, cardiovascular disease, colonic cancer and diabetes. Dietary fiber was defined by Trowell *et al.* (1976) to include plant polysaccharides and lignins which are resistant to hydrolysis by the digestive enzymes of man. The Federation of American Societies of Experimental Biology has recommended a daily consumption of 20–35 g of DF from various foods (Andres, 1987). Owing to its quantitative importance in the diet, potato is a significant source of DF. The DF content of raw potato apparently ranges between 1 and 2 g/100 g fresh weight (Paul & Southgate, 1978; Jones *et al.*, 1985). However, heat treatment during commercial processing and domestic cooking may affect the physico-chemical properties of dietary fiber, which in turn may alter its physiological role in the human body (Payne, 1987). Cooking has been shown to increase the dietary fiber content of potato (Johnston & Oliver, 1982; Varo *et al.*, 1984). On the other hand, Jones *et al.* (1985) found no significant change in the DF content of baked, roasted or french-fried potato when compared with raw potato. Wet heat processing, such as boiling, tended to first solubilize and then destroy the pectin substances by degrading galacturonan chains (Keijbets *et al.*, 1976; Anderson & Clydesdale, 1980).

The increase in the DF content of cooked potato may be partly attributed to the formation of resistant starch (RS). The RS is the term applied to the starch fraction that is resistant to the action of amylolytic enzymes and it may be produced by subjecting foods to heat and/or dehydration, which confers a more ordered structure on the starch molecules and renders them less susceptible to enzyme digestion. Jones *et al.* (1985) found that there was little RS in raw potato, but that it formed 20% to 50% by weight of the total dietary fiber (TDF) of cooked potato. The influence of heat treatment on DF and starch components of potato was demonstrated mostly in raw tubers. This study was therefore undertaken to examine the effect of domestic cooking methods (boiling, microwave-heating, baking and deep-fat frying) on the DF and starch composition of selected processed potato products.

MATERIALS AND METHODS

Materials

Common brands of instant mashed potatoes and frozen french fries (partially cooked) were purchased from a local supermarket.

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Sample preparation

Instant mashed potatoes were prepared by boiling or microwave-heating (2450 MHz, 1450 W) a slurry of flakes for 2·5 min to the 'usual' consistency. The water: flakes ratio was 3:2 (v/v). Frozen french fries were thawed and then baked in a conventional oven at 232°C for 16 min or fried in deep fat at 180°C for 2 min.

All samples were blended separately in a commercial chopper and freeze-dried to constant weight. The dried samples were ground to ensure homogeneity and kept in airtight containers in a desiccator at ambient temperature until further analyses.

Determination of SDF, IDF and TDF

The procedure for the determination of TDF is a slight modification of the enzymatic–gravimetric method of Prosky *et al.* (1985). The finely ground samples were gelatinized in the presence of heat stable α-amylase (Sigma Product No. A-5426) and then enzymatically digested with protease (Sigma Product No. P-3910) and amyloglucosidase (Sigma Product No. A-9913) to remove the protein and starch present in the sample. The water-insoluble dietary fiber (IDF) was filtered and washed with water and acetone. The filtrate, containing the soluble dietary fiber (SDF), was retained. The SDF was precipitated with four volumes of 95% ethanol, filtered and washed with ethanol. After drying, the IDF was weighed. Half of the samples were analyzed for protein and the others were ashed. Correction was made for protein and mineral content of the residue. The TDF was the combined soluble and insoluble fiber.

Determination of starch

In-vitro digestible starch (DS) was determined by the modified procedure of Budke (1984) and Bjorck *et al.* (1986) using a Yellow Springs Instrument (YSI) Model 27 analyzer (YSI Co., OH) equipped with a glucose oxidase membrane (YSI No. 2365). A 0·25 g sample of each treatment was weighed into a 25-ml-volumetric flasks. Water (10 ml) was added and the flasks were vigorously swirled. The solutions were placed in a boiling water-bath for 2 h. After cooling, 0·02 ml of calcium chloride reagent (6·25 g of $CaCl_2$/100 ml) and 0·2 ml of α-amylase (Sigma Product No. A-3403) were added and the solutions were incubated for 1 h at room temperature. After that, 2·5 ml of acetate buffer (330 g sodium acetate and 251 g acetic acid in 2 litres water) and 0·2 ml amyloglucosidase (Sigma Product No. A-3042) were added to each solution and incubated for 1 h at 55°C. The samples were then cooled, diluted to volume with water, and filtered through Whatman No. 42 filter paper. The filtrates were allowed to sit for at least 2 h before glucose determination to ensure that α- and β-glucose anomers had reached equilibrium. This is necessary because of the specificity of glucose oxidase for the β-form only. The per cent starch was calculated according to the equation:

$$\% \text{ Starch} = \frac{(R-B) \times 0{\cdot}9 \times 100}{S \times 4}$$

where R = sample's glucose reading, B = Blank's glucose reading, S = weight of sample (mg).

Resistant starch was calculated as the difference between the total starch (TS) determined when samples were solubilized in alkali before enzymatic digestion and the DS that is measured without prior solubilization. Each sample (0·25 g) was solubilized in 4 M KOH (4·5 ml) for 30 min at room temperature. The solution was then neutralized with 2 N HCl (9 ml) and digested by following the procedure as previously described.

Statistics

Data collected from this study were analyzed by one-way analysis of variance and Duncan's multiple range tests using SAS (1985) programs. Pearson correlation analysis was conducted to determine the correlation between IDF and RS contents.

RESULTS AND DISCUSSION

Effect of domestic cooking on DF composition

The influence of cooking on DF composition of processed potato products is given in Table 1. The SDF of both samples remained unchanged during domestic cooking. This phenomenon agrees with the results obtained by Varo *et al.* (1983). The major SDF constituents of potato have been identified as pectin and hemicellulose (Ross *et al.*, 1985). Boiling and microwave-heating appeared to increase the IDF of instant mashed potato. In french fries, deep-fat frying significantly increased the IDF while baking caused only a minor additional change in IDF fraction. Several authors have proposed that the formation of lignin-like substances (Anderson & Clydesdale, 1980; Theander & Westerlund, 1987) and chemically modified indigestible starch (Englyst *et al.*, 1982; Theander &

Table 1. Effect of domestic cooking on dietary fiber composition of processed potato products

Samples	Treatment	%SDF	%IDF	%TDF
Instant mashed potato	Control	3·44*a*	4·15*c*	7·60*c*
	Boiling	3·46*a*	5·14*b*	8·60*ab*
	Microwave-heating	3·57*a*	5·50*b*	9·08*a*
Frozen french fries	Control	2·54*b*	5·32*b*	7·86*bc*
	Baking	2·58*b*	5·71*b*	8·28*abc*
	Deep-fat frying	2·30*b*	6·62*a*	8·92*a*

All analyses were done in duplicate and results are given on dry weight basis. Means within each column with the same letters are not significantly different (α = 0·05). SDF, IDF and TDF represent soluble, insoluble and total dietary fiber, respectively.

Table 2. Effect of domestic cooking on starch composition of processed potato products

Samples	Treatment	%DS	%RS	%TS
Instant mashed potato	Control	66·6*ab*	3·5*d*	70·1*b*
	Boiling	68·1*a*	2·9*d*	71·0*b*
	Microwave-heating	64·5*c*	7·3*b*	71·8*b*
Frozen french fries	Control	65·2*bc*	6·2*c*	71·4*b*
	Baking	65·3*bc*	6·2*c*	71·5*b*
	Deep-fat frying	64·6*c*	9·1*a*	73·6*a*

All analyses were done in duplicate and results are given on dry weight basis. Means within each column with the same letters are not significantly different (α = 0·05). DS, RS and TS represent *in-vitro* digestible, resistant and total starch, respectively.

Westerlund 1987; Ostergard 1989) are responsible for the increased IDF. A similar trend of results was obtained for TDF as compared to IDF. Since the SDF content in processed potato remained constant during cooking, any increase in TDF could therefore be attributed to the elevated IDF level.

Effect of domestic cooking on starch composition

Starch composition of processed potato before and after cooking is displayed in Table 2. In comparison to control potato flakes, microwave-heated mashed potato contained less DS and more RS, while the boiled counterpart produced slight changes. In french fries, baking did not alter the starch composition but deep-fat frying reduced DS and significantly increased the amount of RS.

Different forms of RS that may be present in foods are retrograded amylose, starch that is encapsulated within the plant cell or tissue structure, thermally or chemically modified food starches, native or incompletely gelatinized β-type starch granules, and amylose–lipid complexes (Asp & Bjorck, 1992). Retrogradation of amylose has been identified as the main mechanism for the formation of RS (Berry, 1986). Retrogradation is due to the association of the amylose molecule. The linear amylose chains are hydrogen-bonded; they form aggregates of low solubility and in high concentrations they form gels (Pomeranz, 1985). Potatoes contain 20% amylose (Young, 1984), and 25% of the RS in cooked, cooled potatoes could be accounted for as retrograded amylose (Englyst & Cummings, 1987). Resistant starch consists of relatively short-chains of linear α-(1→4)-glucan within amylose molecules that preferentially crystallize from solution during cooling of cooked starch paste (Russel *et al.*, 1989). Berry (1986) showed that amylopectin starches incubated with α-(1→6)-debranching enzyme, following by heat treatment, produced a high yield of RS (32–46% of total dry weight). In contrast, low yields of RS (0·2–4·2%) were obtained from intact (i.e. non-debranched) amylopectin starches. The data provide evidence for linking RS with changes involving amylose rather than amylopectin. Autoclaving effectively increased the RS content of some starches, presumably because it mobilizes the starch polymers by swelling of the native granule ultrastructure and thereby allows separation of the amylose domain which crystallizes most readily (Russel *et al.*, 1989). This model tentatively explains the phenomenon that occurred in the microwave-heated sample since both cases involved the addition of water. The marked increases in RS and TS in french fries prepared by deep-fat frying may partly be attributed to the formation of amylose–lipid complexes that are resistant to amylolysis (Asp & Bjorck, 1992).

Correlation between IDF and RS

The significant correlation (r = 0·81, P > 0·001) between IDF and RS contents suggested that some of the starch in the potato samples had become indigestible by amylolytic enzymes after cooking, and this could cause the observed increment in the IDF fraction. It appears that previously reported data on DF of heat-treated foods could possibly have been overestimated. It is therefore essential to redefine DF and to decide whether or not RS should be included in DF for food labeling. Perhaps, the main concern of this presently controversial issue may be that it could create an incentive for food manufacturers to explore possible ways for raising levels of RS in processed foods as a means of generating extra 'dietary fiber'.

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