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Acrylamide reduction under different pre-treatments in French fries

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Abstract

Acrylamide formation in French fries was investigated in relation under different processing conditions and the content of glucose and asparagine of the strips before frying. Potato strips (0.8 × 0.8 × 5 cm) of Bintje variety were fried at 150, 170 and 190 °C until reaching moisture contents of ~40 g water/100 g (total basis). Prior to frying, potato strips were treated in one of the following ways: (i) immersed in distilled water for 0 min (control), 60 min and 120 min; (ii) immersed in a citric acid solution of 10 g/L for an hour; (iii) immersed in a sodium pyrophosphate solution of 10 g/L for an hour; (iii) blanched in hot water at six different time-temperature combinations (50 °C for 40 and 80 min; 70 °C for 10 and 45 min; 90 °C for 3 and 10 min). Acrylamide content was determined in French fries while the glucose and asparagine content in the potato strips before frying. Immersed strips in water for 120 min showed a reduction of acrylamide formation of 33%, 21% and 27% at 150, 170 and 190 °C, respectively, when they were compared against the control. Potato strips blanched at 50 °C for 80 min had the lowest acrylamide content when compared against strips blanched at different conditions and fried at the same temperature (135, 327 and 564 μm acrylamide/kg for 150, 170 and 190 °C, respectively). Potato strip immersion in citric acid solution of 10 g/L reduced much more the acrylamide formation after frying than the strip immersion in sodium pyrophosphate solution of 10 g/L (53% vs. 17%, respectively—average values for the three temperatures tested). Acrylamide formation decreased dramatically as the frying temperature decreased from 190 to 150 °C for all the pre-treatments tested. Color represented by the total color difference showed high correlation (r^2 of 0.854) with the acrylamide content of French fries.

Keywords: Potato strips; Frying; Acrylamide; Color; French fries; Glucose; Asparagine

1. Introduction

Potato (*Solanun tuberosum L.*) is one of the words's major staple food crops. In 2003, 310×10^{12} ton potatoes were produced (FAO, 2005). Potatoes are grown in approximately 80% of all countries and worldwide production stands in excess of 300 millions tons/year. US produce over 17.4 billion pounds of frozen and French fried potato products per year (National Potato Council, 1988). Large variation in suitability of potato (*S. tuberosum*) for processing of crisp and French fries have special quality demands compared to ware potatoes.

Deep fat frying is extensively used in food processing both industrially and at home, and fried potato products are one of its largest applications. Frying of potato strips is based on heat transfer from the hot oil, which results in water removal and oil uptake by the piece (Aguilera & Gloria-Hernadez, 2000). Since French fries contain almost 15% fat, pressure to reduce the lipid content of diets has prompted many studies on 10 mechanisms of fat absorption during frying. The desirable characteristics of most fried foods are derived from the formation of a composite

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structure: a crispy outer, porous, and oily outer layer of crust, and a moist cooked interior or core, whose microstructures have been formed during the process (Rosen & Hellenäs, 2002).

It has been confirmed that a wide range of cooked food—prepared industrially, in catering or at home—contain acrylamide levels (μg/kg). This includes staple foods like bread, fried potatoes and coffee as wee as specially products like potato chips, biscuits, French fries, bread, and a range of other heat-processed products. Acrylamide has been classified as probably carcinogenic in humans (Rosen & Hellenäs, 2002; Tareke, Rydberg, Karlsson, Eriksson, & Tornqvist, 2002). In April 2002, Swedish researchers shocked the food safety world when they presented preliminary findings of acrylamide in some fried and baked foods, most notably potato chips and French fries, at levels of 30–2300 μm/kg. As acrylamide has not been detected in unheated or boiled foods, it was considered to be formed during heating at high temperatures. They attributed this fact to the higher temperatures reached in Maillard non-enzymatic browning reactions required for desirable color, flavor and aroma production (Coughlin, 2003). The data published so far indicate that a temperature >100 °C is required for acrylamide formation (Becalski, Lau, Lewis, & Seaman, 2003). Acrylamide is formed by heating above 120 °C certain starch-based foods, such as potato chips, French fries, bread and processed cereals (Tareke et al., 2002). Recently an analytical method for analyzing acrylamide in coffee was validated (Granby & Fagt, 2004).

Reducing acrylamide in food industry wide can only help the public perception about safety, which has suffered in recent years. Studies indicate that acrylamide causes cancer in rats. Among several deep-fat frying technologies, vacuum frying has a significant strategic importance for future fried manufacturing and in reducing acrylamide formation (Garayo & Moreira, 2002; Granda, Moreira, & Tichy, 2004). Some authors diminished acrylamide formation in fried snacks products by adding amino acids such as lysine, glycine and cysteine (Tae Kim, Hwang, & Joo Lee, 2005). On the other hand, lowering the pH with citric acid before frying was an efficient way to considerably diminish acrylamide formation in French fries (Jung, Choi, & Ju, 2003). Some authors reported that by lowering frying temperature at atmospheric pressure of potato chips from 185 to 165 °C, it was possible to reduce the acrylamide formation to a half (Haase, Matthäus, & Vosmann, 2003; Pedreschi, Kaack, & Granby, 2004; Pedreschi, Kaack, & Granby, 2006). These results suggest that there may be ways to reduce or prevent acrylamide formation by changing production and preparation methods.

It has been stated that acrylamide is generated during a side reaction of the Maillard reaction. Crucial participants in this reaction are an amino acid (asparagine) and reducing sugars (fructose and glucose) (Mottram & Wedzicha, 2002). Asaparagine provides the backbone of the acrylamide molecule, while reducing sugars are essential coreactants in the formation of the *N*-glycoside intermediates, which lead to the formation of acrylamide. Fried products, especially French fries and crisps, belong to the food category with probably the highest concentration of acrylamide recorded so far. The reason for this strong susceptibility to acrylamide formation is the abundance of free asparagine present in potato (Zyzak et al., 2003). The acrylamide formation only takes place at temperature above 100 °C (Mathaüs, Haase, & Vosmann, 2004), which makes the frying process and ideal condition. On the other hand, is essential for its contribution to the color and flavor of fried potatoes. Obviously, acrylamide formation will largely be influenced by the potato composition, particularly with regard to its sugar and amino acid content (Fishelier, Hartmann, Fiscalini, & Grob, 2005). Both, potato variety and field site had a noticeable influence upon formation. Acrylamide formation in fried potatoes is related to raw material (potato variety and field site) and the production process (Haase et al., 2003). Acrylamide appears to form as a result of a reaction between specific amino acids, including asparagine, and sugars found in foods reaching high temperatures during cooking processes. The process is known as the Maillard reaction and occurs at temperatures above 100 °C. Variation in suitability of potato tubers for processing is not influenced only by cultivar and storage conditions, but also by differences in normal cultural practice and growing conditions. A low amount of reducing sugars in the tuber is necessary to prevent the non-enzymatic Maillard reaction between sugars and free amino acids during frying (Daheny, 1986). The Maillard reaction is responsible for the development of undesirable dark colored compounds melanoidins with bitter taste. Recently, it was discovered that the potential carcinogenic compound acrylamide also is formed in potatoes at high temperatures (Tareke et al., 2002) and that the precursors for melanoidins and acrylamide might be the same (Mottram & Wedzicha, 2002; Stadler et al., 2002).

Sugars accumulate in potato tubers, when there is an imbalance between starch degradation, starch synthesis, and respiration of carbohydrates. Storage temperature and physiological age of the tubers are the most important factors that affect this process of sweetening. Potatoes aimed for processing are stored at relatively high temperature (e.g. 8 °C). In practice a limit of 1.5–2.0 mg/g of fresh weight of reducing sugars in potato tubers is used as an indicator for suitability for processing (Burton, 1969). Beside diversity in storability between cultivars, large variation is often found between different potato lots/fields of the same cultivar within and between years (Olsson, Svensson, & Roslund, 2004), and hence they should be managed accordingly. Normally, the size of the total free amino acid pool in potato tubers exceeds that of the total reducing sugar pool, and it would be expected that only the latter metabolites limit the degree of color production during storage correlated with darker fry color with an upturn in reducing sugar content (Brierley, Bonner, & Cobb, 1996).