Food Research International 42 (2009) 142–147

Contents lists available at ScienceDirect

Food Research International

journal homepage: www.elsevier.com/locate/foodres

Effect of chemical and biological dipping on acrylamide formation and sensory properties in deep-fried potatoes

Monica Anese *, Renzo Bortolomeazzi, Lara Manzocco, Marisa Manzano, Cristina Giusto, Maria Cristina Nicoli

Dipartimento di Scienze degli Alimenti, University of Udine, Via Sondrio 2/a, 33100 Udine, Italy

ARTICLE INFO

Article history:
Received 4 June 2008
Accepted 17 September 2008

Keywords:
Acrylamide
Consumer acceptability
Deep-fried potatoes
Glycine
Lactic acid fermentation

ABSTRACT

The objective of this work was to study the effect of chemical and biological pre-treatments on acrylamide formation in deep-fried potatoes. Prior to deep-frying, potatoes cubes were subjected to lactic acid fermentation in the presence or in the absence of glycine, as well as to immersion in an aqueous solution of the amino acid alone. The effects of each pre-treatment on deep-fried potatoes were compared by evaluating acrylamide formation, browning development as well as sensory attributes and preference. Results showed that deep-fried potatoes subjected to the glycine and fermentation pre-treatments had 35% and 50% less acrylamide content than the water-dipped ones. Lactic acid fermentation in the presence of glycine resulted the most effective in decreasing acrylamide formation up to 70%. Such a pre-treatment did not affect the sensory perceived browning, flavour, sourness and crispness of the deep-fried potatoes. Moreover, according to the results of a pair comparison preference test, no significant differences in preference were found among the samples.

1. Introduction

High to very high levels of the toxic and suspected carcinogen acrylamide are formed in potatoes during deep-frying, due to both the presence in the tubers of considerable concentrations of acrylamide precursors (reducing sugars and asparagine) and the intense heat treatment applied (Amrein et al., 2003; Becalski et al., 2004; Taubert, Harlfinger, Henkes, Berkels, & Schoemig, 2004). However, the presence of sugars as well as high processing temperatures are indispensable prerequisites in order to obtain final products with the desirable sensory properties. For this reason, the formerly suggested adoption of lower deep-frying temperatures or times to reduce acrylamide formation in potato derivatives often leads to products which are nutritionally unbalanced, because of the high fat content, and with poor sensory properties (Biedermann, Biedermann-Brem, Noti, & Grob, 2002; CIAA, 2007; Fiselier, Bazzocco, Gama-Baumgartner, & Grob, 2006; Haase, Matthaus, & Vosmann, 2003; Kita, Brathen, Knutsen, & Wicklund, 2004; Romani, Bacchiocca, Rocculi, & Dalla Rosa, 2008). It must be pointed out that these negative aspects seem to be overcome if the reduced-temperature process is carried out under vacuum (Granada, Moreira, & Tichy, 2004). Another innovative approach to reduce acrylamide levels in French fries has been recently described (Erdoğdu, Palazoglu, Gokmen, Senyuva, & Ekiz, 2007). This consisted in a microwave pre-cooking step, which resulted to be very effective in minimizing acrylamide formation in French fries. In fact, lower surface temperatures and shorter cooking times are needed to remove water due to the increased tissue permeability caused by the microwave pre-treatment. It is worth to noting that the high costs required to manage the frying process at low pressure as well as difficulty of integration of microwave equipment into an existing factory setting and its management could represent hurdles to industrial exploitation of these strategies. The use of the asparaginase has been also proposed to attain asparagine consumption (Zyzak et al., 2003). Very recently it has been developed asparaginase based on cloning of *Aspergillus oryzae*. This commercial enzyme has also received generally recognized as safe status from US, and a positive evaluation from the Joint FAO/WHO Expert Committee of Food Additives (JEFCA, 2007; Kuilman & Wilms, 2007). Asparaginase is claimed to reduce acrylamide levels by up to 90% by converting asparagine into aspartic acid without altering the appearance or taste of the final product (Vang Hendriksen et al., 2006). Pedreschi, Kaack, and Granby (2008) found that soaking of blanched potatoes strips in a 10,000 ASNU/L asparaginase solution at 40 °C for 20 min led to the production of fried potatoes with 60% less acrylamide content than blanched strips without the enzyme pre-treatment. According to these Authors, although asparaginase pre-treatment is a very promising tool for acrylamide mitigation, its use requires optimization of processing parameters as well as introduction of process changes.

* Corresponding author. Tel.: +39 0432 558153; fax: +39 0432 558130.
E-mail address: monica.anese@uniud.it (M. Anese).

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doi:10.1016/j.foodres.2008.09.008

At the moment, the most reliable acrylamide mitigation strategies in terms of industrial applicability are relevant to agronomical interventions, aimed to reduce sugar and asparagine concentration in tubers, and technological strategies to be carried out before deep-frying (CIAA, 2007). Among the latter are blanching and pH reduction. Blanching, which is already applied in order to avoid burns formation in fried potatoes as well as to promote partial starch gelatinization, thus reducing fat uptake, is responsible for leaching of acrylamide precursors (Haase et al., 2003). The kinetic control of the rate of acrylamide formation by means of pH reduction can be achieved by using organic acids or by lactic acid fermentation (Fredriksson, Tallving, Rosen, & Aman, 2004; Gama-Baumgartner, Grob, & Biedermann, 2004; Kita et al., 2004; Baardseth et al., 2006; Pedreschi, Kaack, & Granby, 2006). It must be pointed out that in the case of fermentation an additional hurdle to acrylamide formation may be represented by glucose consumption by the microorganisms (Baardseth et al., 2006; Kaaber, Sundt, & Slinde, 1995). Acrylamide mitigation can be also achieved by adding to food amino acids able to compete with asparagine for sugar or to favour acrylamide degradation (Rydberg et al., 2003; Wedzicha, Mottram, Elmore, Koutsidis, & Dodson, 2005). Among the amino acids studied, glycine was the most effective (Bråthen, Kita, Knutsen, & Wicklund, 2005; Rydberg et al., 2003). The effects of combined treatments of acidification by means of citric acid and of addition glycine or soy protein hydrolyzed in reducing acrylamide levels in potato model systems are reported (Cook & Taylor, 2005; Low et al., 2006). By employing a combination of such treatments, acrylamide reduction as well as minimization of the loss of volatile compounds responsible for flavour profile can be better achieved than by applying the treatments individually.

It must be pointed out that, although all these technological pre-treatments have been claimed to significantly reduce acrylamide formation, their effects on the quality of the finished products have been almost always evaluated by instrumental analyses (Amrein, Limacher, Conde-Petit, Amado, & Escher, 2006; Gokmen & Senyuva, 2006; Low et al., 2006; Pedreschi et al., 2006). On the contrary at our knowledge very little information is available on the effect of such treatments on the sensory properties of potato derivatives as determined by consumer or panel tests. To date only one investigation deals with the impact of lowering-acrylamide pre-treatments on the sensory quality of potato crisps (Mestdagh, De Wilde, Delporte, van Peteghem, & De Meulenaer, 2008). However, only chemical pre-treatments, such as blanching in solutions containing different salts, organic acids or amino acids, were considered.

In the light of these considerations, the present study was aimed not only to reduce acrylamide formation but also to favour the development of the desired sensory properties of deep-fried potatoes. To this purpose, lactic acid fermentation in the presence or in the absence of glycine, as well as immersion in an aqueous solution of the amino acid alone, were considered as pre-treatments of potato cubes before deep-frying. The effects of each pre-treatment on deep-fried potatoes were compared by evaluating acrylamide formation, browning development as well as sensory attributes and preference.

2. Materials and methods

2.1. Preparation of lactic acid bacteria culture

The modified methodology suggested by Baardseth et al. (2006) was adopted. A *Lactobacillus plantarum* DSM 20174 strain was used. The strain was grown at 30 °C overnight in 800 mL of MRS broth (Oxoid, Milan, Italy) and harvested at a maximum density of 5×10^9 colony forming units (CFU/mL) corresponding to an optical density of 0.97 at 600 nm using a spectrophotometer (Smart Spec™ 3000, Biorad Milan, Italy). The cells were centrifuged (Beckman, Mod. Avanti centrifuge J-25, Palo Alto, CA, USA) at 12,000g for 20 min at 4 °C. The pellet was washed twice with sterile distilled water and then diluted to a final concentration of 9×10^8 CFU/mL with sterile distilled water or with an aqueous solution of 0.05 M glycine.

2.2. Sample preparation

Potato tubers (*Solanum tuberosum* cv. "Primura"), were purchased on a local market. Initial sugar concentrations in the tubers are reported in Table 1. Data are in agreement with those reported by other Authors for potatoes to be fried (Amrein et al., 2003; Kaaber et al., 1995). Potatoes were peeled, cut into cubes (10 mm side) using a hand-operating potato cutter. The potatoes cubes were then subjected to the following pre-treatments:

(a) dipping in sterile distilled water (hereafter also reported as water);
(b) fermentation in sterile distilled water containing *L. plantarum* at 9×10^8 CFU/mL (hereafter also indicated as LAB);
(c) fermentation in a 0.05 M glycine aqueous solution containing *L. plantarum* at 9×10^8 CFU/mL (hereafter also reported as LAB-GLY);
(d) dipping in a 0.05 M glycine aqueous solution (hereafter also indicated as GLY).

In all cases, the potato:liquid ratio was 1:2 (w/w). The pre-treatments were carried out in a cell thermostated at 37 °C for 75 min, which represented optimal conditions for lactic bacteria fermentation. Non-dipped potatoes were also considered. After dipping, samples were wiped and immediately deep-fried. Five grams of potato samples (approximately seven cubes) per sampling were deep-fried in 3 L of vegetable oil at 180 °C ± 3 °C for 90 s, by using an electrical fryer (Moulinex AF 1003, Milano, Italy), equipped with a static basket and a regulating thermometer. After frying, the potato cubes were drained and wiped to remove excess of oil.

2.3. Analysis of acrylamide

2.3.1. Sample extraction

An aqueous solution of 1000 μL of 2,3,3[$^2H_3$] acrylamide (d_3-acrylamide) (0.99 μg/mL) (Isotec, Sigma–Aldrich, Italy) as internal standard and 15 mL of water Milli Q (Millipore, Italy) were added to 1 g of finely ground sample weighed into a 100 mL centrifuge

Table 1
Glucose and total sugar concentrations, and pH values of deep-fried potatoes subjected to the following pre-treatments at 37 °C for 75 min: dipping in sterile distilled water (water), dipping in a 0.05 M glycine aqueous solution (GLY), fermentation in sterile distilled water containing *Lactobacillus plantarum* at 9×10^8 CFU/mL (LAB), fermentation in a 0.05 M glycine aqueous solution containing *Lactobacillus plantarum* at 9×10^8 CFU/mL (LAB-GLY)

Pre-treatment	Glucose (mg/g_{dm}[A])	Fructose (mg/g_{dm}[A])	Sucrose (mg/g_{dm}[A])	pH
Non-dipped	20.4 ± 1.3[a]	19.6 ± 2.3[a]	1.46 ± 0.3[a]	5.98 ± 0.52[a]
Water	21.3 ± 0.4[a]	16.1 ± 0.1[a]	2.7 ± 0.1[a]	5.87 ± 0.31[a]
GLY	21.2 ± 0.2[a]	16.2 ± 0.1[a]	2.3 ± 0.3[a]	5.83 ± 0.31[a]
LAB	23.6 ± 2.9[a]	19.8 ± 3.3[a]	2.9 ± 0.1[a]	5.36 ± 0.10[b]
LAB-GLY	21.4 ± 0.5[a]	16.3 ± 0.2[a]	2.3 ± 0.5[a]	5.32 ± 0.13[b]

Sugar concentrations and pH of the untreated deep-fried potatoes are also reported (non-dipped).
Different letters in the same column indicate significant difference ($P < 0.05$) by Tukey test.
[A] Dry matter.