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Citric acid to reduce acrylamide formation in French fries and roasted potatoes?

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Introduction

Acrylamide is a probable carcinogen (1) and is formed in roasted, baked or fried foods from the free amino acid asparagine supported by a carbonyl compound, usually a reducing sugar (2). Owing to a high content of asparagine and a rather high consumption, fried and roasted potato products are of first concern for acrylamide exposure (3).

Recently *Jung, Choi and Ju* (4) reported that acrylamide formation in corn chips and French fries can be substantially reduced by acidification of the starting material with citric acid. For French fries, 25 % less acrylamide was obtained after extraction of the potato sticks with plain water (1 h at RT), removing reducing sugar and asparagine from the most strongly heated surface layer. Treatment with 1 % citric acid resulted in a reduction by 73 %, that with 2 % citric acid by 80 %. The pH of the juice squeezed from the potato treated with 1 or 2 % citric acid dropped from 6.2 to 5.2 and 4.9, respectively. Since acrylamide is formed by a Maillard-type reaction, this dependence on acidity is not surprising.

The authors state that the browning was not affected by the treatment with citric acid, i.e. that acrylamide formation is independent of browning. Further they did not detect a taste difference when using up to 1 % citric acid.

We noticed the effect of pH during the investigation of the background of acrylamide formation (5). The addition of 5 % citric acid to potato reduced the acrylamide concentration by about a factor of two, which was the result of the acrylamide formation being more strongly decreased than the also substantially reduced acrylamide elimination. Addition of sodium carbonate also reduced the acrylamide concentration, in this instance because the higher pH accelerated elimination more effectively than the formation of acrylamide.

The work presented in this note aimed at a more detailed evaluation of the use of citric acid for the reduction of acrylamide in French fries and roasted potatoes. For the French fries, suitable concentrations of the citric acid and the duration of the treatment were investigated. For the roasted potatoes, where acrylamide concentrations may be particularly high (sometimes reaching 5000 µg/kg), experiments were driven by the hypothesis that relatively high concentrations of acid could be applied onto the thin surface layer ending up being roasted, having a correspondingly strong effect without a disturbing sensorial impact on the whole product. Cooked potatoes, as commonly used for preparing roasted potatoes, cannot be immersed in acidified water, since they decay.

Experimental

French fries were prepared from potatoes of the cultivars Ostara (harvested middle June and obtained from a farmer; potential of acrylamide formation (6), 800 µg/kg) and three lots of Charlotte (harvested in 2003, obtained from local market in July 2003; potentials for acrylamide formation of 160–240 µg/kg). They were pealed and cut to sticks of 10 mm thickness. Incomplete marginal pieces were removed (about ⅓ of the rather small potatoes). 200 g of the selected sticks were immersed in 0.5 l water (usually tap water from the boiler of about 60 °C) containing citric acid at the concentrations indicated in the results. Immersion usually lasted 15 min; agitation was avoided to minimize starch being washed out of the opened cells (3). 2 l of frying oil (Suprema Universal-Pflanzenöl, Migros, Zurich, Switzerland) was heated by a 600 W laboratory heating plate equipped with a regulating thermometer and agitated by a magnetic stirrer. Potato sticks were immersed using a basket of a household frier. 200 g of potato were pre-fried at 140 °C (dropping to 120–130 °C) for 4 min, then fried at 170 °C (dropping and remaining at 150 °C) during 6 min. Acrylamide was analyzed as described in reference (7).

Roasted potatoes (in Switzerland called "Rösti") were prepared by a method similar to the description in (8), minimizing acrylamide formation. The potatoes of the cultivar Charlotte used for the principal experiment, harvest in 2003 and bought in July 2003, had a potential for acrylamide formation of 210 µg/kg. They were boiled, stored overnight in the refrigerator and grated (holes 2×5 mm) and homogenated. Portions of 300 g were formed to a cake of 16 cm diameter in a frying pan containing 10 ml preheated oil. After 3 min (before noticeable browning), the cake was turned and the heated surface sprayed with 4 ml of acid solution, applying a sprayer as widely used in households. After another 3 min, the cake was turned again and sprayed also on the other side with 4 ml of diluted acid. Then side 1 was heated for additional 9 min, side 2 for 7 min, resulting in similar browning. The volume of acid solution sprayed on to the surface was chosen to well soak the layer later browned during roasting without rendering it really wet.

Results

French fries

The first experiments were performed with Ostara potatoes with a rather high potential of acrylamide formation (800 µg/kg), probably owing to premature harvesting. This explains the high acrylamide contents in the resulting French fries. As shown in table 1, a 15 min treatment with 0.25 % citric acid reduced the acrylamide content by a factor of two (from 810 to 400 µg/kg). Most of this effect was due to extraction of asparagine and reducing sugar into water, as confirmed by the comparison of an extraction into warm water and warm solution of 0.25 % citric acid (290 and 250 µg/kg, respectively; lines 6 and 7). At higher concentrations, citric acid rapidly became more effective: at 1 %, the reduction amounted to a factor exceeding three, and the increase from 1 to 2 % reduced the acrylamide content by another factor of almost three. However, in agreement with *Jung et al.*, 2 % citric acid had a clearly noticeable sensorial effect.

Table 1
Effect of immersion in citric acid or lemon juice for 10 × 10 mm potato sticks prepared from Ostara potatoes

	Treatment	*Acrylamide (µg/kg)*
1	No treatment	810
2	0.25 % Citric acid in cold water	400
3	0.5 % Citric acid in cold water	270
4	1 % Citric acid in cold water	130
5	2 % Citric acid in cold water	50
6	Warm water	290
7	0.25 % citric acid in warm water	250
8	Warm water with lemon juice	290

Particularly for preparation in the household, the use of lemon juice instead of citric acid would be more acceptable. With the juice of half a lemon in the 0.5 ml of water, the acrylamide content could not be reduced. In fact, the concentration of citric acid was about 0.2 %, and the citric acid in lemon is not fully protonated. Addition of lemon juice directly to the potato sticks was sensorially unacceptable.

Figure 1 shows the acrylamide contents in French fries prepared from Charlotte potatoes (potential of 240 µg/kg) treated with 1 % citric acid during the times indicated (combining the effects of extraction into water and acidification). Conditions were selected to slightly over fry in order to obtain more significant differences. Treatment during 2 or 5 min in the boiler-warm water containing 1 % citric acid reduced the acrylamide content of the French fries from 250 to about 150 µg/kg (i.e. by 40 %). Prolongation to 10 and 20 min reduced it by 63 and 80 %. After 1 h, the reduction reached 91 %. Treatment during 10 min in cold (10 °C) instead of warm water reduced the acrylamide by 35 instead of 63 %.

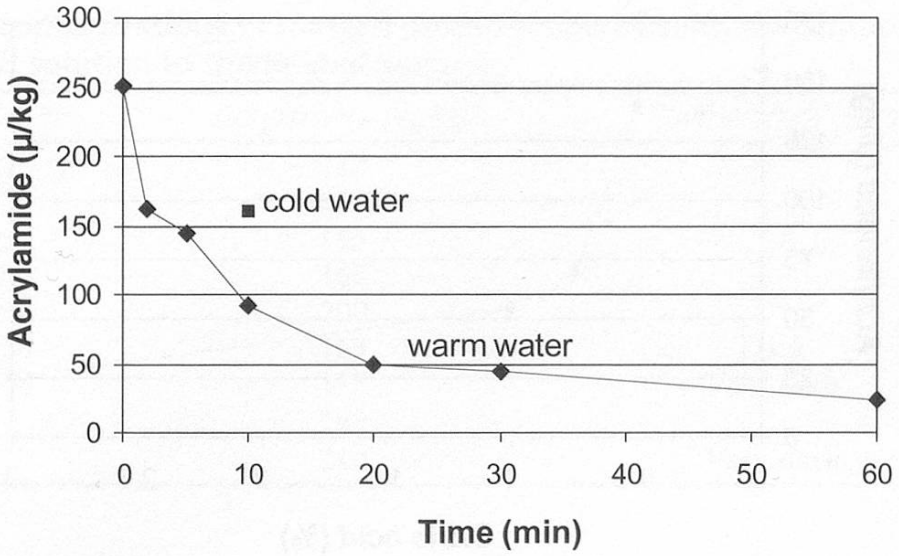

Figure 1 **Acrylamide contents in French fries pre-treated by 1 % citric acid in cold or boiler-warm water during the times indicated**

For samples treated with 1 % citric acid during up to 10 min, no sensorial effect was noticed (five test persons). For some test persons, treatment during 20 min left a slight taste of acidity. The latter was clearly noticeable for the sample treated during 1 h. It was concluded that citric acid penetrates the potato slowly and the threshold for a noticeable effect is reached at after 15 min.

Browning paralleled the acrylamide concentration. Without watering, all sticks had some browned regions. With 5–10 min in the acid solution, approximately half of the sticks showed some browned spots, with clearly stronger browning for the sample immersed in the cold solution. The samples kept in the solution for 20–30 min showed only few browned spots, that treated for 1 h none at all.

Jung et al. mentioned that citric acid did not influence the color of the product. This observation could not be confirmed in our work. At modest concentrations, citric acid clearly reduced browning, whereas it enhanced it when applied in high concentrations (see also table 2). Perhaps these two effects were just balanced under the conditions applied by these authors.

Figure 2 shows the acrylamide contents in French fries from a similar lot of Charlotte potatoes (potential of 170 µg/kg). The concentration of citric acid is varied, using warm water from the boiler (60 °C when leaving the tap) for 15 min. In this experiment, the effect of extraction into water was constant, i.e. only the effect of acidification is observed. In accordance with the results obtained with the Ostara potatoes, the strong effect is observed with citric acid at concentrations above about 0.5 %. At 1 % citric acid, two out of five test persons tasted the acid. The strong reduction obtained with 3 % citric acid (a factor of six) is therefore, of no practical use.

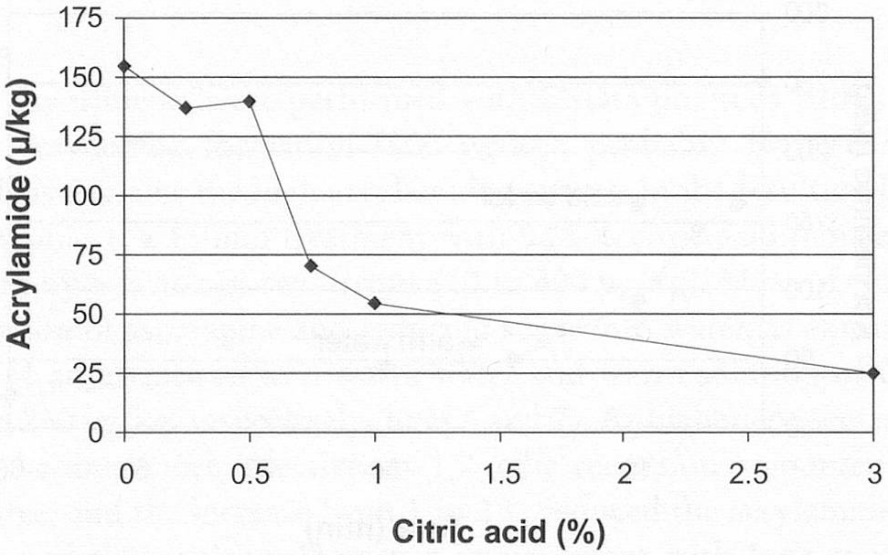

Figure 2 **Acrylamide in French fries pretreated for 15 min in warm water or solutions of citric acid with the concentrations indicated**

Roasted potatoes

Table 2 shows the results for cooked and grated potato roasted to the point reaching satisfactory crispiness (minimized acrylamide formation). Without treatment with acid, the product contained 210 µg/kg acrylamide. In a control experiment, 4 ml water was sprayed on each side of the potato cake. This had no effect on acrylamide formation, probably because the small amount of water applied to the warm surface evaporated rather rapidly.

Application of acid produced disappointing results. With solutions containing 1–30% citric acid, the acrylamide contents could not be lowered to a relevant extent, and already at 4% citric acid, there was a clearly noticeable sensorial effect. The products became darker when 10 or 30% citric acid were sprayed on to them, presumably because of decomposed starch.

Hydrochloric or phosphoric acid were not more successful in lowering acrylamide concentrations than citric acid. Phosphoric acid rendered the product very dark and had a negative sensorial effect. Further experiments with Agata and Ostara potatoes confirmed these results. In some experiments, citric acid solutions or lemon juice were applied using a brush.

Table 2
Acrylamide concentrations in roasted potato prepared with the application of water or acid solution to the heated surface

	Acrylamide (µg/kg)	*Deviation of color*
Not sprayed	210	
Water	210	
1 % Citric acid	185	
2 % Citric acid	165	
4 % Citric acid	200	
10 % Citric acid	165	Dark
30 % Citric acid	175	Very dark
2 % HCl	160	
3 % H_3PO_4	210	Very dark

Conclusions

Acidification of the potato prior to frying or roasting, as suggested by *Jung et al.* (4), is an attractive approach to reduce acrylamide formation, but is limited by the effect on the sensorial quality of the product.

For roasted potatoes (Rösti), where an improvement would be particularly welcome, no significant effect could be achieved. Furthermore, the assumption that a relatively thin layer of roasted potato could be acidified rather strongly without a noticeable sensorial effect on the final product proved to be wrong. The significant complication of the cooking procedure is not justified by a reduction of perhaps 20 %.

As demonstrated by *Jung et al.*, acidification during the pretreatment of French fries is more promising. The potato sticks are anyway watered or even blanched, and often citric acid is added in order to improve the color stability of the prefabricate, i.e. the application of citric acid to reduce acrylamide contents does not imply additional steps in the preparation of the potato sticks.

The results show that the window of the citric acid concentration having a positive effect, but no noticeable impact on the sensorial quality is narrow: 0.25 % citric acid has little effect, whereas 1 % is at the upper limit. 0.75 % citric acid applied in warm water for some 15 min decreases acrylamide concentrations by well a factor of two – in addition to the effect resulting from extracting asparagine and sugars into the water. The same effect is obtained in shorter time when the concentration of citric acid is around 1 %. This improvement is most welcome and should be taken into serious consideration, primarily for the preparation of prefabricated French fries.

Summary

The potential of reducing acrylamide contents in roasted potato (Rösti) and French fries through acidification of the potato was explored. Acids sprayed onto the surface of the potato cake to be roasted had no sufficient effect to justify the extra efforts involved. For French fries, a reduction by a factor of well two can be achieved when adding 0.75 % citric acid to warm water in which the potato is immersed for

about 15 min (in addition to the effect of extracting asparagine and reducing sugar). The window of favorable concentrations is narrow: 0.25 % citric acid showed little effect, while the French fries had an acidic taste when 1 % is exceeded.

Zusammenfassung

Die Möglichkeiten wurden untersucht, die Acrylamidbildung in Rösti und Pommes frites durch Ansäuerung der Kartoffel zu vermindern. Aufsprühen von Säure auf die zu röstende Oberfläche von Röstis brachte keine Verbesserung, die den zusätzlichen Aufwand rechtfertigen würde. In Pommes frites kann der Acrylamidgehalt um einen guten Faktor zwei vermindert werden, indem die Stängel ca. 15 min in Boiler-warmem Wasser mit 0,75 % Zitronensäure eingelegt werden (zusätzlich zum Effekt der Extraktion von Asparagin und reduzierendem Zucker). Das Fenster der geeigneten Konzentrationen ist eng: 0,25 % Zitronensäure reduzierte die Acrylamidgehalte kaum, während Konzentrationen über 1 % die Pommes frites sensorisch störend beeinflussten.

Résumé

Les possibilités de réduire la formation d'acrylamide dans les pommes de terre poêlées (rösti) et frites par acidification ont été examinées. L'acide déposé à l'aide d'un nébuliseur sur la surface chauffée des röstis n'a pas apporté une réduction qui justifierait les efforts supplémentaires à investir. Pour les pommes frites, une réduction d'un facteur de bien deux peut être obtenue en immergeant les pommes de terre pendant environ 15 minutes dans une solution tiède avec 0,75 % d'acide citrique (en plus de l'effet de l'extraction de l'asparagine et des sucres réducteurs par l'eau). La fenêtre des concentrations favorables est étroite: 0,25 % ne montre que peu d'effet, et au-dessus de 1 % le produit prend un goût acide.

Key words

Acrylamid, potato products, French fries, roasted potatoes, citric acid

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