Acrylamide Formation during Frying of Potatoes: Thorough Investigation on the Influence of Crop and Process Variables

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Abstract: Acrylamide, which is a suspected human carcinogen, is particularly formed in starch-rich foodstuffs, like potato. The inter- and intraspecies variability of the potato causes a dispersion in the amount of acrylamide. This intraspecies variability can be influenced through agricultural practices and storage conditions. By assessing these factors, advice to potato producers can be given in order to lower the formation of acrylamide during frying.

Keywords: acrylamide formation; potatoes; extrinsic and intrinsic variables

INTRODUCTION

Detection of high concentrations of acrylamide in common heated starch-rich foodstuffs by the Swedish National Food administration in April 2002 [1] attained public concern because this process contaminant is a suspected human carcinogen. Particular concern about its formation in staple food like potato and cereal products has risen. For potatoes, especially French fries and crisps are susceptible for acrylamide formation and therefore this study is focused on these products [1]. Acrylamide formation was found as a result of the Strecker degradation, which is a side-reaction of the Maillard reaction between reducing sugars (glucose or fructose) and an amino group. An important role in this reaction is the amino acid asparagine. Potatoes are very rich in that amino acid, which is mainly present in its free form [2].

Because of the economical importance of potato production and use, there is a need to determine the factors which influence the formation of acrylamide in fried products. These factors can be of intrinsic or extrinsic nature. Intrinsic factors vary with the composition of the raw material, while extrinsic factors are influenced by the agricultural treatment of the crop. For the intrinsic factors, special attention will be paid to the amino acids in particular asparagine and the reducing sugars. The extrinsic factors which will be investigated are storage conditions, fertilization, type of soil, reconditioning and different types of varieties. Storage of potatoes below 8°C and storage over long periods of time causes an increase in the concentration of reducing sugars; which consequently increases the potential for acrylamide formation. Sowokinos [3] found that reconditioning potatoes by storing them at higher temperatures for 2–3 weeks will lower levels of reducing sugars and consequently the potential for acrylamide formation. However, reconditioning for 2–3 weeks will not reduce reducing sugar levels to the original levels and leads to

increased time and expense for the grower. Storage at 8°C minimizes low-temperature sweetening, but increases disease problems and requires use of sprout suppressants. Little is know about the influence of fertilization, some found a correlation between the nitrogen content of the soil and the amino acid content, however, some experiments have shown that nitrogen fertilizers have no effect on the levels of asparagine [4].

The aim of this research is to find a screening tool for breeders for assessment of acceptable amounts of acrylamide in potatoes after frying.

EXPERIMENTAL

Samples. Research I. Samples (Bintje (B), Saturna, (S), Ramos (R)) were taken every 2 or 4 weeks; starting from mid October. The samples were stored for 10 months at 4°C or at 8°C. At 8°C CIPC was used, at 4°C a difference was made between potatoes stored with (code: 5) and without CIPC (code: 4). Cultivation was done under different types of fertilization and haulm killing: A (advice N, normal haulm killing), V (Advice N, early haulm killing), H (advice N/2), N (no fertilization). Every two months a reconditioning sample was taken, this was stored at 15°C after cold storage, for 3 weeks (R3) and 5 weeks (R5). Research II. Samples: 11 French fry varieties (1–11), 5 chips varieties (21–25) were taken every four weeks, starting from the 2nd week of January. These samples were stored for 8 months at 8°C (code: 9) in the dark and treated with chlorpropham (CIPC). In total 5 points of time were used. The potatoes were cultivated on two soil types: a clay soil (WO) and a sandy loam soil (IE).

Sample preparation. From every sample 20 tubers were taken, from each tuber, a French fry of 10 × 10 mm was cut out in length. This was taken out of the centre of the tuber. The twenty obtained French fries were fried. The rest material was cut into cubes of 1 × 1 cm and frozen at –18°C. *Determination of sugars in raw potato.* Mono- and disaccharides were assessed using a gas capillary chromatograph equipped with a flame ionization detector. *Determination of starch in raw potato.* Determination was carried out using a polarimeter. *Determination of dry matter.* Determination by weight loss trough heating. *Determination of the total and free nitrogen*. Free Nitrogen. After precipitation of the proteins with TCA, Kjeldahl analysis was performed on the filtrate. Total Nitrogen. Determined with Kjeldahl procedure. *Determination of the free amino acid profile*. Amino acid analysis was carried out using a Biotronik LC3000 amino acid analyzer. The technique was based on the separation of the amino acids using cation exchange chromatography followed by the ninhydrin colour reaction and photometric detection at 570 nm.

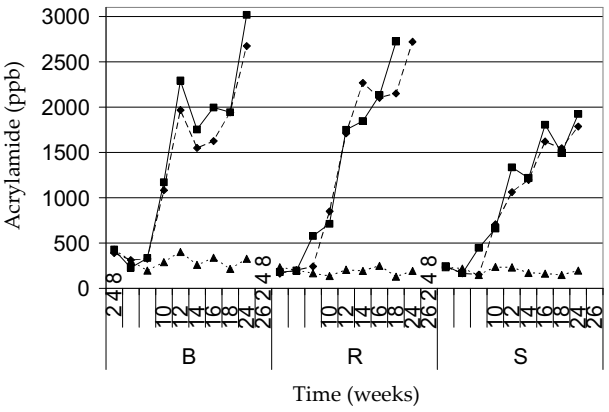
Determination of pH and titrable acids. pH was measured with an electrode and the titrable acids determined with a titration with NaOH. *Baking of the French fries*. The fries were par-fried for 3 min at a temperature of 180°C in arachid oil followed by a finish fry for 2 min at the same temperature. After frying the samples were homogenated and analyzed for acrylamide with LC-MS/MS.

RESULTS AND DISCUSSION

Research I

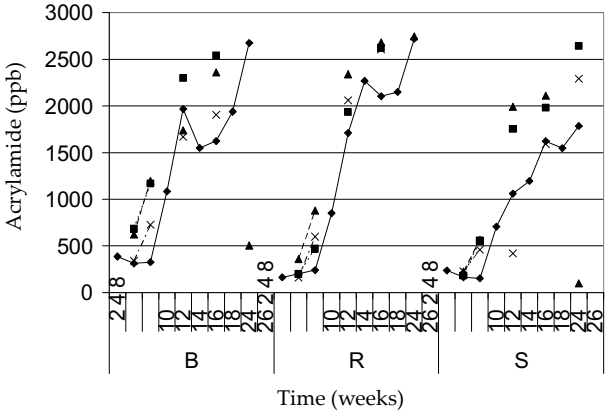
Influence of storage time, temperature and variety on acrylamide formation. The amount of acrylamide for potatoes stored at 4°C was higher than potatoes stored at 8°C. The amount of acrylamide increases strongly in time for potatoes stored at 4°C, in contrary to potatoes stored at 8°C. The use of CIPC had no direct influence on the acrylamide concentration. The amount of acrylamide is lower for Saturna than for Ramos and Bintje stored at 4°C (Figure 1).

Influence of storage time, temperature and variety on fructose, glucose and sucrose. The influence of the temperature was clear for glucose and fructose, less for sucrose. The amount of glucose and fructose was higher in potatoes stored at 4°C.



–◆– 4–A; –■– 5–A; …▲… 9–A

Figure 1. Influence of storage temperature and time on the amount of acrylamide for one fertilization level



–◆– 4–A; –▲– 5–H; …■… 4–N; –∗– 4–V

Figure 2. Influence of fertilization in time on the formation of acrylamide for three varieties for storage at 4°C

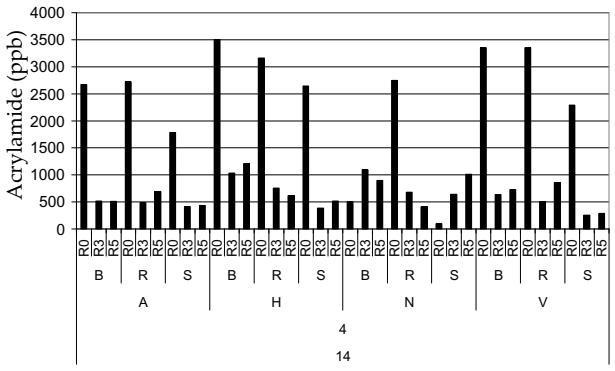


Figure 3. The effect of reconditioning on the formation of acrylamide for 3 varieties, stored for 24 weeks at 4°C without CIPC for 4 fertilization levels

Because of the absence of data, the trend in time was not very clear, but there appeared to be an increase in time. The difference between varieties was minimal.

Influence of storage time, temperature and variety on dry matter, starch, pH, titrable acids, free and total protein. No noticeable influence of time, temperature and variety could be found for these parameters.

Influence of fertilization on the amount of acrylamide. The amount of acrylamide is shown for three varieties in function of time and four fertilization levels in Figure 2. There was an indication that with a normal fertilization level the formation of acrylamide was less high than when less or no fertilization was added to the soil.

Influence of fertilization on dry matter, starch, pH, titrable acids, fructose, glucose and sucrose. Out of the comparison between the four levels of fertilization, there appeared no influence of fertilization on these parameters.

Influence of fertilization levels on free and total nitrogen. The amount of total and free nitrogen was higher with increasing amount of fertilization. An equal amount of protein could be found for the three varieties and the amount of protein did not vary much in time. There was also no influence of the use of early haulm killing.

Influence of reconditioning on the amount of acrylamide. The effect of reconditioning is shown in Figure 3. The amount of acrylamide decreases after storage for 3 weeks at 15°C. The cause of this effect can be found in the decrease of the sugars during this storage. The difference between storing them for 3 or 5 weeks is small, so reconditioning for 3 weeks is more favorable, because storing them for 5 weeks has the disadvantage that the germ will be too big for processing.

Research II

Influence of the variety and type of soil on the amount of acrylamide. In Figure 4, the amount of acrylamide is presented as a function of the type of soil for all varieties. High amounts of acrylamide were registered for variety Tebina (10) and Asterix (8), but there was no clear influence of the type of soil on the amount of acrylamide. The amount of acrylamide is higher for the French fry varieties than for the chips varieties.

Influence of storage time on the amount of acrylamide. There was no clear influence of time on the amount of acrylamide in a range of four months stored at 8°C with CIPC for all varieties.

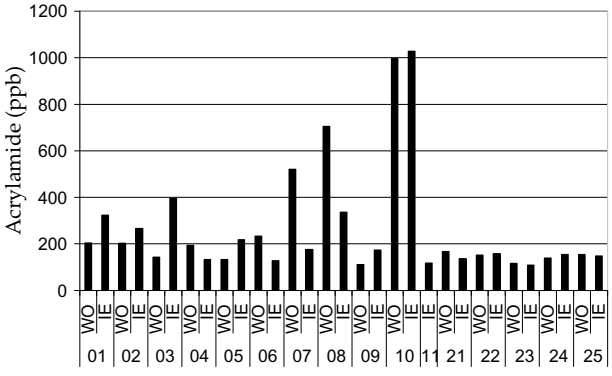


Figure 4. Influence of potato variety and type of soil on the amount of acrylamide

Amount of mono- and disaccharides in function of storage time. There was a little increase noticeable in time for the sugars fructose, glucose and sucrose.

Difference between two types of soil and storage time on other parameters. No difference was found in the amount of total and free protein between the 2 types of soil, but a small increase in time was found. For the amino acid aspargine, there appeared to be an increase in time, up to half the starting value. For pH, titrable acids, starch there appeared no trend in time and in type of soil. For dry matter, no trend was found in time, but the dry matter was lower on the clay soil.

CONCLUSIONS

Storage of potatoes at low temperatures is not advisable for frying of potatoes. Reconditioning potatoes could be a solution for cold storage, but this has its disadvantages. The level of nitrogen fertilization appears to have an influence on the formation of acrylamide, when no fertilizers are added to the soil, more acrylamide is formed. Concerning interspecies variability, it can be concluded that variety Tebina (10) has the highest formation of acrylamide, and seems least suitable for frying.

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