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A methodology for evaluating the formation and human exposure to acrylamide through fried potato crisps

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Abstract

Potato crisps are a popular snack food which have been implicated as a potential source of acrylamide. This study develops a farm-to-fork human exposure assessment model for acrylamide in fried potato crisps for Irish consumers. The model used Monte Carlo simulation techniques to model the various stages from on farm production of potatoes, storage, processing, crisp production and final human consumption of potato crisps. A baseline model is created and a number of scenarios are subsequently created to look at the impact of different model assumptions and input parameters. The baseline model found that the mean level of acrylamide in potato crisps in Ireland was 720 μg/kg. Irish consumer exposure to acrylamide in potato crisps was estimated to be 0.052 and 0.064 μg/kg bw/day for males and females, respectively. A sensitivity analysis revealed the important parameters influencing the model predictions. The initial level of reducing sugars was found to be the most important parameter (correlation coefficient 0.58 and 0.57 for glucose and fructose, respectively), highlighting the importance of selecting cultivars with low reducing sugar levels for crisp production. The cooking regime had a significant impact on model predictions, highlighting the need for further research into the impact of different time and temperature combinations. Blanching and soaking of potatoes were also identified as important risk reduction processes.

Keywords: Risk assessment; Acrylamide; Potato crisp; Simulation

1. Introduction

Crisps are a potato snack product popular in the UK and Ireland (referred to in the US as potato chips). Crisps were first produced in the USA in 1853 and were further developed in Ireland and around Europe under various brand names. In the Republic of Ireland alone approximately 16,000 tonnes of savory snacks were consumed with a retail market value of €192 million in 2004 (C&C, 2005). The crisps category is the largest constituent of this market, accounting for 65% of the total savory snacks market by weight (C&C, 2005). The crisp production process involves the immersion of wafer thin slices of potato in cooking oil, typically sunflower oil or rapeseed oil (Tayto, 2005), at high temperatures (>165 °C) and may therefore be considered a dehydration process (Hubbard & Farkas, 1999). These conditions lead to high heat transfer rates, rapid cooking, browning, texture and flavour development (Farkas, Singh, & Rumsey, 1996). The sensory properties of the crisps are largely influenced by the heat transfer rates. The frying process is often used in conjunction with a flavouring process resulting in numerous flavours, colours and textures.

Potato crisps were identified as a food product with potential for high levels of acrylamide formation (Tareke, Rydberg, Karlsson, Eriksson, & Tornqvist, 2002). Some researchers report significantly higher levels in potato crisps compared to French fries (Dybing & Sanner, 2003). Given their popularity as a snack food, particularly among younger age groups, it is important to assess the daily intake of acrylamide from crisps and to quantify its contribution to overall human intake of acrylamide in the Irish diet. This paper aims to assess the level of acrylamide formation in fried potato crisps and to assess the level of human exposure to acrylamide in Ireland through fried

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potato crisps by developing a farm-to-fork Monte Carlo simulation model for potato crisps. This paper details the development of a baseline model and includes a scenario analysis to look at the impact of different process conditions and different cultivar usage.

2. Baseline model development

The limiting factor in the formation of acrylamide appears to be the level of the reducing sugars, glucose and fructose, in the raw potato product (Amrein et al., 2003; Becalski et al., 2004). Hence an understanding of the factors affecting the levels of reducing sugars in potatoes will aid in the understanding of acrylamide formation and possible interventions to reduce this formation. This study models acrylamide formation in potato crisps using largely empirical data to model reducing sugar levels, modelling potato growth, storage, subsequent processing and cooking procedures. This is achieved by means of Monte Carlo simulation techniques. Data relating to the various stages involved in the crisp making process was collated from existing scientific literature and relevant stages were modelled with respect to their impact on reducing sugar levels and consequently acrylamide formation. A table of model inputs and distributions is provided in Appendix A. A flow diagram of the crisp process modelled is given in Fig. 1.

To account for the inherent uncertainty in the model and variability of the system, input parameters were represented as distributions rather that point estimates. Monte Carlo simulation from these inputs then generates an output distribution with corresponding confidence limits. Monte Carlo methods randomly select values from given distributions to create multiple scenarios of a problem. Each time a value is randomly selected, it forms one possible scenario and solution to the problem. Together, these scenarios give a range of possible solutions, some of which are more probable and some less probable resulting in a probability distribution for the solution parameter. A schematic of the Monte Carlo simulation process is given in Fig. 2. Following harvest a given cultivar will have a certain level of reducing sugars; this is represented by a distribution, as some potatoes will have higher levels than others. If these potatoes then go through a period of storage this may impact on the original distribution to give a new distribution for the level of reducing sugars following

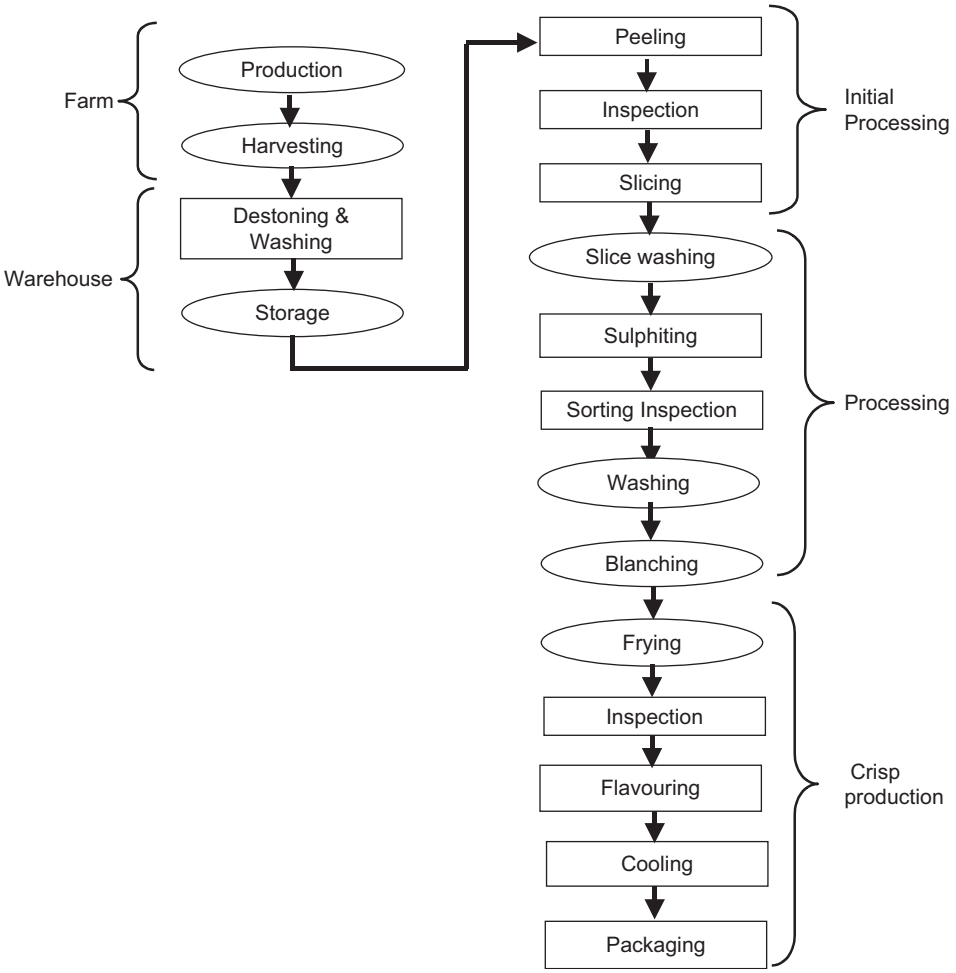

Fig. 1. Flow diagram of fried potato crisp production.