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The effect of different decontamination methods on the microbial load, bioactive components, aroma and colour of spice paprika

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ABSTRACT

Among condiments, paprika is one of the most important ones used both for flavouring and improving other sensorial properties of foods. Because of their agricultural origin, spices are often naturally contaminated with various bacteria due to poor sanitation during growth, harvest, drying, and storage. In this study different decontamination methods were compared regarding microbial decontamination efficacy and maintaining the biochemical, aroma and colour properties. Irradiation and steaming, were found to be highly effective for microbial decontamination of spice paprika powders. Only slight changes were detected due to the decontamination treatment for bioactive component content, however significant changes were observed in the levels of volatile aroma compounds. Alternative decontamination methods, such as microwave heating alone and combined with re-wetting and intensive mixing, or radio-frequency heat treatment alone were also performed to evaluate the effect of these treatments. These methods were found to be less effective in the reduction of the mesophilic aerobic total bacterial counts, while the levels of moulds were significantly reduced, if the samples were held for 10 min at the given incubation temperatures. The treatments did not significantly affect chemical compositional parameters, but sample colour was appeared adversely affected.

1. Introduction

Dried powdered spices are widely used in food products including at all levels of processing from raw materials to inclusion in convenience foods. Among condiments, paprika is one of the most important, used both for flavouring and improving other sensory properties of foods. Because of their agricultural origin, spices are often naturally contaminated with various bacteria, therefore they often constitute a microbial hazard due to poor sanitation during growth, harvest, drying, and storage (Eliasson, Isaksson, Lövenklev, & Ahrné, 2015). The most frequently identified pathogenic bacterial species (Ivnitski, Abdel-Hamid, Atanasov, & Wilkins, 1999) being *Salmonella* spp., *Bacillus cereus* and *Escherichia coli*. The use of contaminated spices without any treatment against bacterial growth can drastically reduce the shelf-life of liquid condiments or spiced food products (due to their low water activity, the storage stability of dried spices is less affected), and may even cause food-borne diseases. Therefore, food products without microbial decontamination or other intensive heat treatment (e.g. cooking) in their processing require special attention (Hertwig et al., 2015), which also applies to spice products for table use. Currently, there are no microbiological criteria for dried spices in the European Community legislation. However, the Codex Code of Hygienic Practice specifies that dried spices should be free of pathogenic microorganisms at levels that may represent a health hazard (Codex Alimentarius Commission, 1995). The European Spice Association (ESA) and the European Commission (EC) Recommendation 2004/24/EC specify that *Salmonella* spp. should be absent in 25 g of spice (ESA, 2004; EC, 2004), *E. coli* must be under 10^2 cfu/g, and other bacteria requirements should be agreed between the buyer and the seller (Muggeridge, Lion, & Clay, 2001). Nonetheless, the use of these techniques is hindered by various technological and societal difficulties. The aerobic total cell counts mostly range between 10^5 and 10^7 cfu/g, the majority being spore-

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formers. The numbers of coliforms, *E. coli* and yeast are low, as also the mould count, which is between 10^2 and 10^4 cfu/g for the majority of the products (Korbász et al., 2007).

The largest spice importer in the world is the EU, where internal spice paprika consumption is also significant. Currently the most important spice paprika growers (Valle-Algarra, Mateo, Mateo, Gimeno-Adelantado, & Jiménez, 2011) and producers in the EU are Hungary and Spain. Even though paprika powder production is significant in these countries, due to the high cost of paprika growing, the amount of paprika imported from overseas countries such as Peru, Brazil, Morocco, South Africa, Nigeria, Zimbabwe, India and Pakistan is increasing (Almela et al., 2007). However, developing countries often have climatic conditions that enable fungal proliferation and production of mycotoxins. In addition, they often lack the technology and infrastructure necessary for adequate manufacturing practices and routine food quality monitoring (Buckenhüskes & Rendlen, 2004). Paprika is usually sold in form of dried products and microorganisms cannot grow or proliferate in them due to the low water activity. However, when the dried spice is used in a food with higher water activity, microbes, including pathogens, can start to multiply to levels that could constitute a risk to consumers (Staack, Ahrné, Borch, & Knorr, 2008).

Microbial contamination cases are readily listed in the Rapid Alert system for Food and Feed (RASFF) of the EU (EC-RASFF Portal, 2016). The RASFF portal reported 14 and 9 notifications for pathogenic microorganisms in chili and paprika powder, respectively, between 2003 and 2016. Paprika powder samples in most cases were contaminated with *Salmonella* (6 cases) species and members of the *Bacillus* genus (2 cases) and on one occasion (Valle-Algarra et al., 2011) *E. coli* O157:H7 was detected.

A severe technological difficulty in decontamination of spice paprika is the resistance of certain target microorganisms, especially sporulating ones, in a medium with low water activity. However some of the traditional paprika processing technological steps (e.g. drying) also act to decrease microbial cell-counts because of the low water activity, allowing more or less uniformly reduced microbial contamination levels in paprika. Several spice decontamination techniques can be incorporated into the processing technology, and occur usually after the grinding step (Schweiggert, Carle, & Schieber, 2007). Current worldwide available decontamination technologies include irradiation, steaming or chemical treatment with ethylene oxide. Although these techniques have been proven to significantly reduce microbial populations, they either have disadvantages in their toxicological consequences (ethylene oxide) or on the composition, aroma, flavour or colour of the finished product (steaming); or may have poor consumer acceptance (irradiation) (Waje, Kim, Kim, Todoriki, & Kwon, 2008). Due to its carcinogenic potential to humans, the use of ethylene oxide is prohibited in the EU (Fowles, Michel, & McGrath, 2001). Gamma irradiation is authorised (and even advised) in the EU to be used for decontamination of dried herbs and spices with a maximum average dose of 10 kGy (Farkas, 2006), even though the sensory and antioxidative properties of the finished product may be slightly affected (Chytiri, Goulas, Badeka, Riganakos, & Kontominas, 2005). The application of high-temperature steaming is effective against contaminating microorganisms, but it can decrease the volatile oil content, cause colour degradation, and may increase the moisture content of dried paprika product, which then reduces shelf-life (Demirci & Ngadi, 2012). Moreover steaming is not suitable for spore inactivation. Considering the above-mentioned disadvantages and problems, the development of other potential decontamination techniques that could be used to produce high quality and microbiologically safe spice paprika is necessary. Emerging technologies include the use of high hydrostatic pressure (Butz, Heinisch, & Tauscher, 1994), application of pulsed electric fields (Keith, Harris, Hudson, & Griffiths, 1997), infrared radiation (Erdoğdu & Ekiz, 2011; Erdoğdu & Ekiz, 2013; Eliasson, Libander, Lövenklev, Isaksson, & Ahrné, 2014), microwave radiation (Dababneh, 2013), ultraviolet radiation or cold atmospheric plasma treatment as a non-thermal technology (Hertwig et al., 2015). Although these technologies are well known for their antimicrobial efficiency and have already found certain utility using the food industry, their application for dry products still has limitations. Certain factors limit decontamination efficiency of these technologies, i.e. heat sterilization is improper if thermally sensitive spice aroma and flavour components are present; and microwave treatment is ineffective for samples of low moisture content.

Various techniques in decontamination technology have been evaluated for their utility in spice production, yet studies mostly focus on the efficacy in the reduction of the microbial load in dried spices. Less emphasis placed on the consequences of the technological step on the chemical or bioactive composition, aroma profile and colour characteristics of the finished product. The aim of this study was to compare the effect of different decontamination techniques, namely irradiation, steam treatment, microwave heating and radio- frequency heat treatment on the microbial load, bioactive components, aroma and colour of spice paprika. Bioactive components (e.g. carotenoids, tocopherols, vitamin C) present as natural constituents in different foods, especially in paprika, provide health benefits beyond the basic nutritional value of the product. The aroma of spice paprika is produced by the simultaneous presence of a number of volatile compounds including terpenes, hydrocarbons, esters, and carotenoid derivatives.

2. Material and methods

Standards (β-carotene, α-tocopherol, γ-tocopherol, ascorbic acid) and chemicals (potassium hydroxide, sodium chloride, sodium sulfate, metaphosphoric acid, potassium dihydrogen phosphate, potassium dichromate, cobalt ammonium sulfate) were purchased from Sigma (Sigma-Aldrich, Alcobendas, Spain). Solvents (1,2-dichloroethane, acetone, methanol, isopropanol, acetonitrile, *n*-Hexane 95% (for HPLC), *n*-Hexane (analytical reagent), ethanol, sulphuric acid, bidistilled water) used were of “analytical”, “HPLC” grade due and were supplied by VWR (Darmstadt, Germany).

Raw (untreated) spice paprika, used for laboratory experiments, was obtained from three sources: industrial batches were provided by FUCHS GmbH (Dissen, Germany) (used for irradiation and radio-frequency treatments), Kalocsai Fűszerpaprika Zrt. (Kalocsa, Hungary) (used for steam treatment), and a batch from an earlier study by the Food Science Research Institute (FSRI), National Agricultural Research and Innovation Centre (Hungary) (used for microwave/enhanced microwave treatment). Irradiation, enhanced microwave and radio-frequency heat treatments were carried out at laboratory scale, while steam treatment was performed in Kalocsai Fűszerpaprika Zrt. in an industrial device. Sampling was performed for each process treatment from the same stock spice before and after the treatment, but the stock was changed during the different treatments. The use of a single stock for all treatment types would have provided better consistency among the data from the treatments, however, the use of different stocks was unavoidable among laboratory and industrial treatments. As various batches of spice paprika from two industrial sources were used in the different decontamination experiments, the initial (control) parameters varied significantly, even orders of magnitude in microbiological parameters among the treatment methods assessed. This reflects the actual situation for industrial spice paprika batches originating from different source countries.