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Quality assurance in microwave food processing and the enabling potentials of solid-state power generators: A review

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ABSTRACT

The widespread deployment of microwaves in domestic, commercial and industrial food processing operations, necessitates quality assurance. This review critically assesses key microwaved-food quality assurance issues such as process lethality, product degradation mechanisms, non-uniform heating and volumetric temperature sensing. Non-uniform heating, the root-cause of quality assurance problems, is shown to have negative consequences on process energy consumption, and linked to the poor controllability of conventional microwave power sources, magnetrons. A case is therefore made for the use of solid-state generators as alternative power sources by a cost-benefit analysis, which includes energy and reliability aspects. The feasibility of a paradigm shift to solid-state power delivery in the development of smart processing systems, is shown, and potential commercialisation opportunities, identified.

Contents

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1. Introduction

The significant rise in consumer demand for minimally-processed, microbiologically-safe and chemical additive-free foods, necessitates continuous innovation in food processing. As traditional thermal processing systems are limited by low heat transfer rates, and hot wall with cold centre effects, volumetric heating methods are desirable for delivering safe foods of high nutritional and sensory quality. Microwave heating is a promising technology in this regard, finding increasing application in a wide variety of domestic, commercial and industrial food processing operations, globally. As at 2014, about 92% of UK households have microwave ovens, mainly for food (ONSUK, 2017, - Fig. 1). A market penetration rate of 101% (some households have multiple microwave ovens), was reported in the UK in 2016 (Euromonitor International, 2017). Over 70 million microwave ovens are sold annually worldwide, with about 14.5 million unit shipments into the United States; while the global number of microwave ovens in operation is in the order of 1 billion (Osepchuk, 2013). Industrial and commercial applications of microwave heating technology in food processing are also on the increase, ranging from tempering of frozen meat and poultry products; precooking of bacon for food service; to cooking of sausages (Ahmed and Ramaswamy, 2007). Others include food drying; baking of bread, biscuit, and confectionery; thawing of frozen products; blanching of vegetables; heating, sterilisation and pasteurisation of fast food, cooked meals, and other foods. Given the widespread end use, and far-reaching implications on public health, it is of utmost importance to ensure that foods processed in microwave systems are of high quality, in terms of microbial safety, nutritional and sensorial attributes. The need for microwaved food product quality assurance therefore, cannot be overemphasised.

Although faster and more volumetric than conventional heating, microwave heating suffers from non-uniform volumetric temperature distribution due to the uneven distribution of dielectric and thermal properties across most foods, as well as microwave standing wave and finite penetration depth phenomena. The result is the formation of cold spots which define the limits of food microbial safety, and hot spots, associated with the degradation of vital product sensory and nutritional quality attributes. If the mechanisms of target microbial/enzyme inactivation and the degradation of quality attributes are well-understood, appropriate processing conditions can be enforced to simultaneously assure these aspects of food quality. The chosen processing conditions must be capable of delivering as uniform as possible lethality and minimum degradation across the entire product volume for optimum performance. There must also be a way of accurately measuring and ideally, controlling in real-time, such lethality across the entire volume of the product, for quality assurance. As thermal effects remain the main lethality mechanism known today

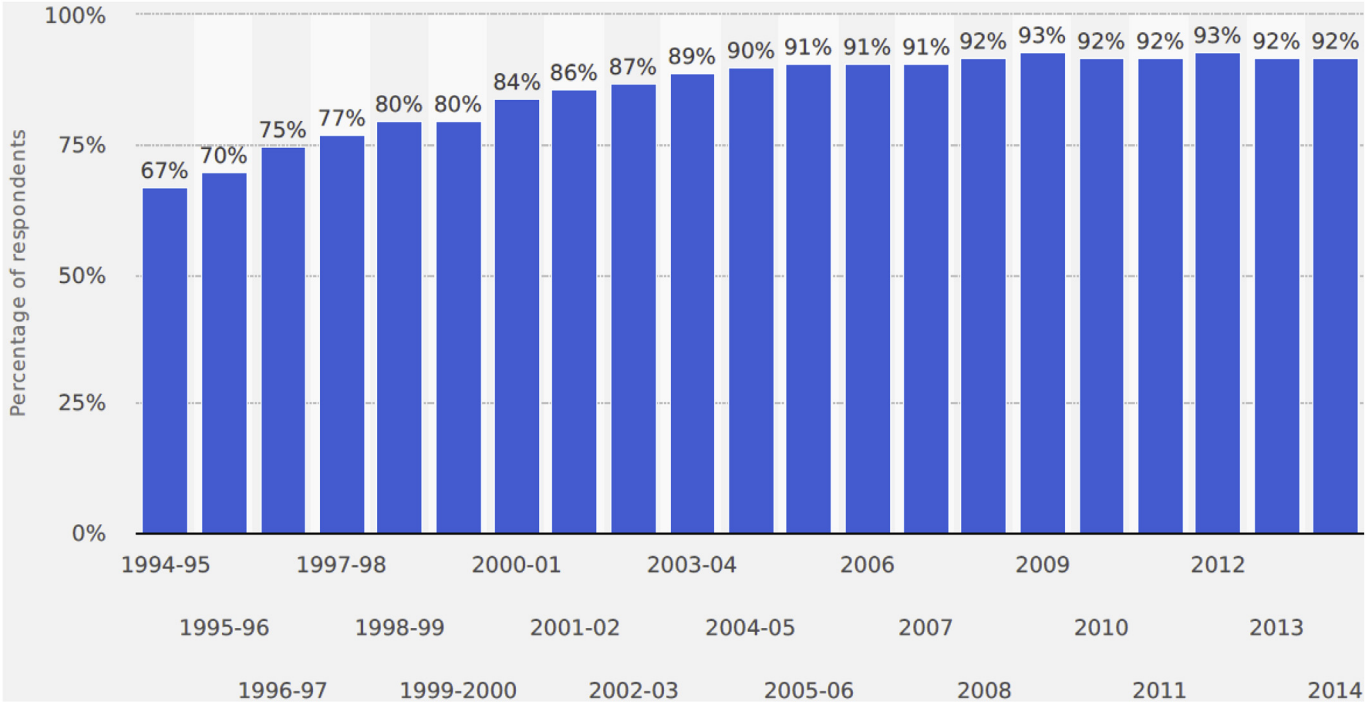

Fig. 1. Percentage of households with microwave ovens in the United Kingdom from 1994 to 2014.