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ScienceDirect

Energy Procedia 123 (2017) 196–203

Energy Procedia

www.elsevier.com/locate/procedia

1st International Conference on Sustainable Energy and Resource Use in Food Chains, ICSEF 2017, 19-20 April 2017, Berkshire, UK

The vulnerability of refrigerated food to unstable power supplies

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Abstract

This paper describes a simplified model for estimating the vulnerability to spoilage of a number of refrigerated foods in households, resulting from interruptions to the electricity power grid. The tool is demonstrated on a sample of three foods (milk, chicken and fish) in India, which historically has suffered significant interruptions. The effect of interruptions is quantified in terms of tonnage and monetary value of potential losses, in a number of simple scenarios. These losses are estimated for rural and urban areas of each Indian state. Our model indicates that extensions to the duration of power supply interruptions increases potential losses in domestic refrigerators, and that these losses are considerable when compared to losses expected in previous stages of the food supply chain. The current model's estimation of weight of food lost may be converted to a nutritional value, which opens an opportunity for new multidisciplinary areas of research.

Peer-review under responsibility of the scientific committee of the 1st International Conference on Sustainable Energy and Resource Use in Food Chains.

Keywords: food waste; food loss; refrigeration; grid supply; power interruption

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1876-6102
Peer-review under responsibility of the scientific committee of the 1st International Conference on Sustainable Energy and Resource Use in Food Chains.
10.1016/j.egypro.2017.07.238

1. Introduction

In recent decades, although there have been significant improvements made to the productivity of agriculture, losses and wastage of food are still common in many agricultural systems, food supply chains (FSC) and in households. Food losses, in India, occur predominantly during the early stages of the FSC, with significant amounts of food becoming unfit for human consumption due to poor handling and a lack of suitable transport. In general, as household income increases, losses and waste shift towards the consumer. As a result, it is likely that losses due to excessive temperatures in household refrigerators may account for a larger proportion of overall FSC losses (including the consumer), than in the same FSC supplying poorer households.

Work by Parfitt et al. [1], citing Grolleau [2], has asserted that food 'losses' occur prior to the retail stage of a food supply chain, and that food 'waste' occurs in either the retail or consumer stages of the chain. Grolleau's definition of food losses post-harvest, is broad and implies that it also encompasses 'waste' stating, "Food loss refers to total modification or decrease of food quantity or quality which makes it unfit for human consumption." [2 Section 2.2]. More recently, the Food Loss and Waste Protocol [3] leaves the definition of waste and losses to the users of the protocol, according to where the food could possibly end up, concentrating on material types and their destinations. The protocol requires its users to quantify the losses and waste by weight, whereupon they may then also establish the loss/waste "in terms of environmental impact, nutritional content or financial implications" (p.17).

Note that because this research work is concerned only with refrigerated food that has reached the consumer, this would be classed as 'food waste' under Parfitt et al's [1] existing definition. However, it might also be argued that the degradation of refrigerated food, resulting from interruptions of electricity supplies to household refrigerators, ought to be classified as 'food losses', in the same way that food failing to make its way into a chilled supply chain would be classed as food losses. The argument here is that the consumer has not wasted the food because he/she was not in full control of the circumstances that caused the food to perish, which might be seen as similar to a farmer being unable to get their produce into the chill chain due to circumstances beyond their control.

Refrigerators are generally one of the first white goods appliances to be purchased when a household can afford to own and operate one [4]. The incentive to own a refrigerator is also affected by access to an adequately reliable electricity supply [5] and due to the continuous nature of a refrigerator's operation, this usually means that the electricity supply needs to be from a grid, rather than from a generator. Consequently, this research does not consider refrigerators that are drawing power from a generator and all refrigerators in the model are assumed to be connected to the mains power grid without backup.

Although refrigerators can be common – particularly in urban areas – how they are used can vary considerably in terms of the foods stored within them and the duration of that storage, as indicated by research in the cities of Bangkok and Hanoi, by Smits and Rinkinen [6]. The study showed that the types of food stored in refrigerators were subject to the purchasing decisions of households, which were influenced by a number of complex issues, including levels of trust in the food's origin. As supermarkets penetrate markets, changes in the quality control of food products can occur, due to the supermarkets' requirements for a more standardized shelf life and brand reputation. Thus, changes in diet resulting from increased affluence, access to new food products and the increased ability to store perishable food add to the complexity of establishing exactly what is in consumer refrigerators. Such subtleties are beyond the limited scope and resources of this work, so some assumptions have been made about shopping and storage patterns for the foods modelled.

2. Model development

Models are reliant upon both their data inputs and the model design. At the conception of this model, the precise nature of any data that might be accessible was not known, thus the framework of the model was constructed to allow detailed inputs to be used, or alternatively develop assumptions in accordance with academic and grey literature.

2.1. Data inputs

Data on typical census topics, such as regional/state population numbers and the urban/rural split, were obtained from government statistics. Climatic data inputs came from monthly mean dry bulb temperatures for each state [7].