Food Waste Reduction Using Simulation Modeling: A Case Study of Bakery Products in a Downstream Supply Chain

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ABSTRACT

In response to Sustainable Development Goals 12.3, this study investigated potential interventions to reduce the total food waste within a downstream supply chain of bakery products. Data collected from the supply chain's players, including the wholesaler, the two retailers, and the consumers, were analyzed and used as inputs for a simulation model. First, the experiment was focused on the inventory management of the wholesaler and the retailer. The result suggested that an appropriate inventory replenishment policy could potentially cut 46% of the downstream food wastage. In addition, this study resolved the debate about the influence of the price discount made by the stores on household food waste. The result suggested that the price discount might increase household bakery wastage by 27%, but the total downstream food waste could actually reduce by half. Finally, this study also explored the consumer contribution to this problem and found that 40% of the total downstream food waste could be reduced if the consumers always check their food stock before making any new purchase. These quantified results could support the policy maker and the operator's decisions for a sustainable solution and encourage the consumers to act on the food waste problem.

1. INTRODUCTION

The Agriculture Organization of the United Nations (FAO) reported that 1.3 billion metric tons of food was being lost and wasted each year [1]. Since then we have become more concerned about the effects of this waste crisis on food production and supply chains, economics and the environment. The food supply chain comprises the various activities necessary from primary production to final consumption that is agricultural activities of growing, harvesting, packaging, transportation, storage, distribution, retailing and retail packaging, purchasing for consumption, and disposal for whatever reason. Especially important is the supply chain of foodstuffs with a short "shelf life", the perishables, such as fruits, vegetables, and bakery products.

The food supply chain consumes natural resources, particularly water, and requires significant inputs of fertilizers and chemicals for pest and weed control that may actually have a negative impact on the environment. So, any food waste must be seen as a waste of resources and a waste of the effort put in to produce it, as well as the obvious waste of the product (in a world where hunger is still a significant problem) [2].

The downstream supply chain produces about 931 million tonnes of food waste annually [3]. The United Nations has announced the Sustainable Development Goals (SDGs) that direct the reduction of food waste at the retail and household levels by half by 2030, specifically SDG 12.3 [4]. Policymakers worldwide responded to the statement by implementing regulations and laws in line with the directive goals [5]-[7]. This agreement will let all stakeholders act for sustainable outcomes.

Fresh bakery has been a significant food product for food waste reduction. The figure for bakery waste in the UK household was 500,000 tonnes in 2012, valued at £870 million, which was 11% of the total food waste [8]. It was reported to be 20% in retail [9]. A study of food waste figures of a store in Italy also found that the bakery department produced 31% of food waste volume and contributed to 13% of the store's food wastage cost [10]. Some waste reduction strategies for fresh bakery included improving demand forecasts, redistribution, introducing in-store production during the sales period, and reducing the price of the products near the best-before date [11]. This latter strategy is, however, open a current debate on whether the price discount is good for the supply chain as a whole as the food can just be pushed to the lower supply chain's players, such as consumers, and the problem is not truly solved [12]-[14]. This study emphasizes this question and uses a quantitative method to achieve a quantified measure.

Consumers generate demand signals that are passed up to all players in the supply chain. Therefore, the consumer plays a significant role in food waste reduction, especially in

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