AN MILP MODELLING APPROACH FOR SHELF LIFE INTEGRATED PLANNING IN YOGHURT PRODUCTION

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Abstract. In the production of perishable products such as dairy, meat, or bakery goods, the consideration of shelf life in production planning is of particular importance. Retail customers with relatively low inventory turns can benefit significantly from longer product shelf life as wastage and out-of-stock rates decrease. However, in today's production planning and control systems shelf life issues with regard to specific products or customers are seldom taken into account. Therefore the objective of this paper is to pay attention to these issues. The way to do that is by means of optimization models in which shelf life aspects are integrated into operational production planning and scheduling functions. Specifically we make use of so-called Mixed Integer Linear Programming (MILP) models. Our research is based on an industrial case study of yogurt production. Relying on the principle of block planning, an MILP model for weekly production planning is presented that is based on a combination of a discrete and a continuous time representation. Batch sizing and scheduling of numerous recipes and products on several packaging lines are considered in the model. Overnight production and, hence, the necessity for identifying two different shelf life values for the same batch is also included in the model formulation. Numerical experiments show that near-optimal solutions can be obtained within a reasonable computational time. Finally, the proposed MILP model can be adapted to cover specific features arising in other fresh food industries.

1. Introduction

Production planning of yogurt is certainly one of the most challenging tasks in the dairy industry as the planner has to cope with e.g. an extraordinary high number of products and variants as well as with sequence-dependent set-up times and costs on capital-intensive processing equipment. One important distinctive factor to consider in fresh food production planning is shelf life. Shelf life restrictions directly influence wastage, inventory levels and out-of-stock rates in the retail

outlets. Furthermore, consumers tend to buy the product with the longest possible shelf life. The possibility to offer a longer shelf life than its competitors constitutes a pivotal competitive advantage for fresh food producers. Hence, the consideration of shelf life is crucial for production planning systems in the dairy or other fresh food industries. The remainder of this paper is organized as follows. A short literature review of research of scheduling in make-and-pack production as well as on production planning for perishable products is given in Section 2. An introduction into the production of yogurt is provided in Section 3. In the main part of this paper (see Section 4), a MILP model is presented that integrates shelf life into production planning and scheduling. The model is numerically validated in Section 5. Finally, an outlook is given on its applicability in other fresh food industries.

2. Literature Review

Batch production in the chemical industry can be taken as a reference for the production of yogurt as both must consider numerous variants, which are based on few product types or recipes. In literature, this production environment is named "make and pack production" (e.g. Neuhaus et al., 2002; Méndez and Cerdá, 2002). Major issues of operational production planning are lot sizing and scheduling, which can be performed in one single or two separate planning steps. As set-ups in yogurt production are sequence-dependent, the exact set-up costs and times can only be determined after the sequencing of the orders. Moreover, as sequencing depends on lot sizing, both tasks must be performed simultaneously (c.f. Sikora et al., 1996). Neuhaus et al. (2002) present an approach that simultaneously considers lot sizing and scheduling based on the block-planning principle. By integrating several variants of a product type or recipe into a "block", the complexity of the model can be significantly reduced without being unrealistic. For the determination of the sequence of batches within a block, a "natural" sequence of batches often exists, for example from the lower taste to the stronger or from the brighter color to the darker.

With regard to the consideration of shelf life in production planning, two different avenues can be distinguished. A vast body of literature exists on *inventory management* for perishable products, which covers food products as well as the behavior of radioactive materials, photographic film, prescription drugs, or blood conserves. Nahmias (1982) and Raafat (1991) give comprehensive literature overviews and an analysis of proposed inventory models for perishables. The major drawback of all perishable inventory models is that production issues are almost completely neglected although the shelf life of products is actually determined by their time of production. In addition, production capacities, sequence-dependent set-up times, or production on multiple units or lines are not reflected. Considering the integration of shelf life into *production planning and scheduling*, most re-