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A comprehensive dairy valorization model

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ABSTRACT

Dairy processors face numerous challenges resulting from both unsteady dairy markets and some specific characteristics of dairy supply chains. To maintain a competitive position on the market, companies must look beyond standard solutions currently used in practice. This paper presents a comprehensive dairy valorization model that serves as a decision support tool for mid-term allocation of raw milk to end products and production planning. The developed model was used to identify the optimal product portfolio composition. The model allocates raw milk to the most profitable dairy products while accounting for important constraints (i.e., recipes, composition variations, dairy production interdependencies, seasonality, demand, supply, capacities, and transportation flows). The inclusion of all relevant constraints and the ease of understanding dairy production dynamics make the model comprehensive. The developed model was tested at the international dairy processor FrieslandCampina (Amersfoort, the Netherlands). The structure of the model and its output were discussed in multiple sessions with and approved by relevant FrieslandCampina employees. The elements included in the model were considered necessary to optimally valorize raw milk. To illustrate the comprehensiveness and functionality of the model, we analyzed the effect of seasonality on milk valorization. A large difference in profit and a shift in the allocation of milk showed that seasonality has a considerable impact on the valorization of raw milk.
Key words: raw milk, valorization, production planning, allocation

INTRODUCTION

Dairy processors face numerous challenges resulting both from unsteady dairy markets and from specific characteristics of dairy supply chains. The volatility of demand and prices of dairy products, greater competitiveness, and the increasing regulations that limit access to external markets significantly affect the performance of dairy processors. The European dairy sector is under constant change following, for example, the new European Union (**EU**) dairy policy and the outcomes of ongoing negotiations in the World Trade Organization. In 2003, the intervention prices for butter and skim milk powder (**SMP**) were decreased by 25 and 15%, respectively. Intervention prices act as floor market prices; that is, every national intervention agency in the EU is obliged to purchase, for this price, any amount of dairy commodity offered to them by dairy companies (Womach, 2005). The substantial decline in the intervention price made the production of bulk products less profitable and more risky. Furthermore, in 2003, it was decided to gradually increase milk quotas and completely abolish them in 2015. These changes led to, and likely will continue to lead to, an increase in milk supply. Furthermore, in the last years, the price of milk fluctuated between €27 and €35 per 100 kg. The yearly percentage change in price in 2000 to 2010 reached 22% (LTO, 2011). According to Geary et al. (2010), dairy market fluctuations and price volatility will be a constant challenge to the future dairy industry. Additionally, the enlargement of the EU in 2007 increased the competitiveness on the EU dairy market, thereby making the market more difficult for dairy processors. High competitiveness on the international dairy market requires dairy processors to optimize production and sales to ensure survival (Guan and Philpott, 2011).

The complexity emerging from the uniqueness of dairy supply chains also requires advanced methods for effective dairy supply chain management. In a dairy chain, raw milk (**RM**), the main raw material, is collected from multiple dairy farms scattered throughout the supply area and used for the production of all dairy products. The volume and, in part, the choice of end product (**EP**) to be produced depend on the nutrient content of RM, which changes during the year. The production of dairy products is interrelated: a byproduct (**BP**) of one production process can be used in another production process, which often takes place at a different location. To manage the incoming milk profitably,

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efficient logistics in many domains are required; for example, transport, allocation, and production planning.

A comprehensive model that captures the dynamics of dairy production and incorporates all relevant constraints related to internal and external environments would significantly improve allocation of milk. The results of the literature review provided in the next section clearly indicate the lack of such a model in current use. In this paper, we present a comprehensive dairy valorization model (**DVM**) that optimizes mid-term plans for the allocation of RM and the production of EP and BP while considering all constraints. The model captures all factors that directly or indirectly influence the allocation of RM. Furthermore, the comprehensiveness of the model allows producers to understand the effect of various changing parameters on milk valorization. This is an important advantage, given the constant changes on the dairy market and in the RM supply. The model not only improves milk valorization, therefore, but also provides a good understanding of prevailing production processes. The developed model was verified at the international dairy processor FrieslandCampina (**FC**; Amersfoort, the Netherlands).

We will first present a literature overview and then present the model in 3 steps. First, the conceptual model will be described, then the model will be verified using information from FC, and finally the mathematical model will be formulated. We will discuss the main outcomes of the model and then define and conduct an additional scenario that evaluates the impact of RM seasonality on valorization.

Literature Review

The literature provides various approaches to maximize profit of dairy producers, starting from a general analysis of dairy manufacturing processes (Roupas, 2008), through allocation models that capture parts of the production process (Kerrigan and Norback, 1986; Papadatos et al., 2002; Burke, 2006; Doganis and Sarimveis, 2007), allocation models that aim to allocate milk to all dairy products in a portfolio (Mellalieu and Hall, 1983; Benseman, 1986), and models that represent whole dairy supply chains (Wouda et al., 2002; Vaklieva-Bancheva et al., 2007; Guan and Philpott, 2011). Given the purpose of this paper and the specific characteristics of the dairy supply chain, we have focused on papers presenting models that aim at the allocation of RM to final dairy products. Readers interested in complete state-of-the-art production planning models may refer to the following review papers: production-distribution models (Vidal and Goetschalckx, 1997; Bilgen and Ozkarahan, 2004; Chen, 2004; Ahumada and Villalobos, 2009), maintenance and production (Budai et al., 2008), production planning and uncertainty (Sahinidis, 2004; Mula et al., 2006; Wazed et al., 2010), production and transport (Mula et al., 2010), and predictive modeling of manufacturing processes (Roupas, 2008).

Even though the dairy production problem has been treated in many ways, a model that takes into account all factors necessary to create a comprehensive DVM is, to the best of our knowledge, not yet available in the literature. A complete list of important factors affecting the valorization of RM was identified, based on a literature study and interviews with experts. Models available in the literature and focusing on the allocation of RM to EP were investigated with respect to included factors. To verify the list of factors, we studied in detail the environment and processes of one of the world's largest dairy companies (FC). Additionally, iterative sessions were held with dairy supply chain managers, production planners, technologists, and market analysts at FC. During these sessions, intermediate results were discussed. This pragmatic stepwise approach of literature and process analyses resulted in the final list of factors (Table 1).

To investigate the models presented in the literature, we began with the framework developed by Ahumada and Villalobos (2009) and extended it with model features that are especially relevant for mid-term dairy production planning. Additionally, we looked at the applicability of these models in practice. We analyzed the papers with respect to the following characteristics: modeling technique; modeling approach (deterministic or stochastic); planning horizon (single period, short-term, mid-term, or long-term); recipes based on milk composition (yes or no); seasonality of RM composition and RM supply included (yes or no); part of product portfolio covered—whole product portfolio (yes) or a particular product group (no; e.g., cheeses or yogurts); BP reutilization (yes or no); BP transport (yes or no); RM transport (yes or no); network of supply regions and production locations (yes or no); changes in product prices—throughout the whole planning horizon, within planning periods that determine the complete planning horizon, and no changes included (no); model tested on a real-life case—application (yes or no). The results of the analysis are presented in Table 2. As can be seen, none of the models available in the literature included all factors relevant to efficient milk valorization. A milk allocation model that included most of the important features was developed more than 25 yr ago (Benseman, 1986). The seasonality aspect of milk components was partly incorporated in that model; that is, volumes of EP obtained from 1 t of RM depend on the composition of milk; however, volumes of BP are fixed. In reality, this is not true because milk composition affects both