



## Selecting food process designs from a supply chain perspective



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### ARTICLE INFO

#### Article history:

Received 11 May 2016

Received in revised form

12 September 2016

Accepted 17 September 2016

Available online 21 September 2016

#### Keywords:

Food industry

Product portfolio

Process design

Facility location

Supply chain configuration

Optimization

### ABSTRACT

The food industry can convert agro-materials into products using many alternative process designs. To remain competitive, companies have to select the design leading to the best supply chain performance. These designs differ in the technologies used and the product portfolio produced. Additionally, characteristics, such as seasonal production and quality decay of food products, lead to specific requirements regarding processing, transportation and storage. The importance of these characteristics of the food industry on process design selection is investigated using sugar beet processing as an illustrative case. The characteristics are included in a multi-period, multi-product location-allocation model. The model shows that a supply chain perspective leads to changes in process design selection. The design with the best portfolio value and processing costs does not lead to the best supply chain performance. This shows the importance of a chain perspective to avoid sub-optimization in food process design selection.

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### 1. Introduction

Developments in resource availability, consumer trends and legislation require the food industry to regularly evaluate their mode of operation to remain competitive (van der Padt, 2014; van der Goot et al., 2016). This includes aligning strategic and tactical decisions on supply chain (SC) organization, the product portfolio produced, and the process design (Chopra and Meindl, 2015). Companies therefore have to select the process design from a range of alternatives on a regular basis to arrive at the best SC performance.

A process design is the combination of process steps or technologies used to convert an agro-material into products. Commonly, selection of a design is done by assessing alternative designs (through experiments or modelling) based on their technical performance characteristics such as yield, costs, or emissions to the environment (e.g. Leone et al., 2015; Manfredi and Vignali, 2015). Such a comparison leads to the selection of a design without taking into account the related SC.

The performance of a design is influenced by the specific

characteristics of the food industry. The food industry is distinguished from other industries by characteristics such as seasonality, specific legislation, and changing product quality (van der Vorst and Beulens, 2002; Bourlakis and Weightman, 2004; Tsolakis et al., 2014). This is especially the case in the agro-food industry, the part of the food industry concerned with conversion of agro-materials into a set of semi-finished and finished products (Fig. 1). It relies on agro-materials, making seasonal and regional production and processing more important than for the food manufacturing industry, which does not rely on harvested crops or animals but on the use of commodity food products or ingredients (van der Padt, 2014). The characteristics of the food industry lead to specific requirements for transportation, storage, and processing. The food supply chain (FSC) for a process design is therefore relevant for selecting the best design, and selection of a design should be based on the performance of the entire FSC (Hosseini and Shah, 2011; Jonkman et al., 2015).

Existing process evaluation and selection models generally do not take the characteristics of the food industry into account (Datta, 2016). These models therefore require adaptations to support process design evaluation and selection in the food industry. An approach illustrated in Fig. 2 is required to include the influence of the FSC in selecting the preferred process design. After a process design is synthesised, simulation of the technical performance can

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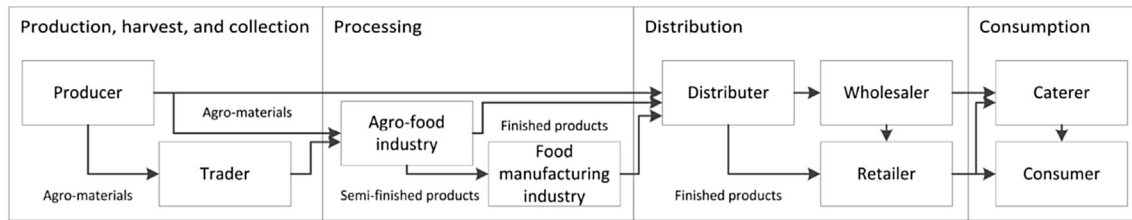


Fig. 1. Schematic representation of the stages and actors in a food supply chain, and the principal flow of products between these actors.

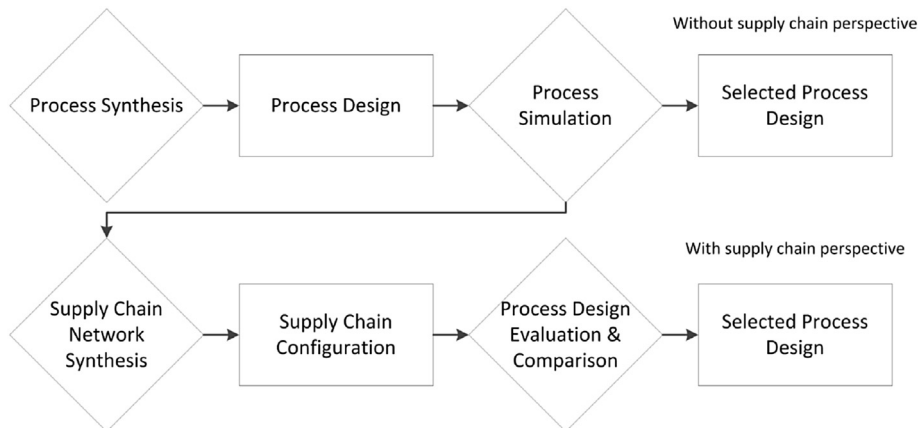


Fig. 2. Food process design evaluation and selection with and without a supply chain perspective.

be used to evaluate the process design and compare it with alternative designs. To include the FSC in this comparison, the performance of the process designs is included in the synthesis of an SC configuration. The performance of the SC configuration provides the basis for selecting the preferred process design from an SC perspective.

The importance of the characteristics of FSCs for process design selection is investigated in this article. Selection of a design based on the technical performance is compared with selection from an SC perspective for an illustrative case on sugar beet processing in The Netherlands. Existing models from the fields of Process Systems Engineering (PSE) and Operations Research (OR) are discussed, and a model is adapted to incorporate the specific characteristics of FSCs relevant to the case. In Section 2, the specific characteristics of FSCs and related work in the fields of PSE and OR are discussed. Section 3 shows that adapting existing methods to account for the characteristics of FSCs provides new insights into the selection of process designs, using the illustrative case study. The effect of specific FSC characteristics on the selection of process designs is discussed in Section 4. In Section 5, conclusions are drawn for the general case of selecting food process designs from an SC perspective.

## 2. Selecting food process designs

Selecting food process designs from an SC perspective requires evaluating and comparing process designs while taking the specific characteristics of FSCs into account. The most important FSC characteristics for selecting process designs are discussed in Section 2.1. The PSE and OR literature was reviewed, and an overview of tools for comparing process designs is presented in Section 2.2, focussing in applications for food process designs.

### 2.1. FSC characteristics

The characteristics that distinguish FSCs are discussed in [van der Vorst and Beulens \(2002\)](#), [Bourlakis and Weightman \(2004\)](#) and [Tsolakis et al. \(2014\)](#). Of these, seasonality in production, the multi-product nature, and specific requirements regarding transportation, storage and processing to maintain product quality are the most important FSC characteristics affecting the process design performance.

Most agro-material production is seasonal, making the agro-material available only at a specific time in a certain region. A processor has to store the agro-material or source it from different regions around the world to operate the processing equipment throughout the year; operate a flexible process to switch to other agro-materials when a season has ended; or decide to only operate the equipment during the season in which the agro-material is available. These decisions influence the performance of a design and should therefore be considered when selecting a process design.

Processing an agro-material inherently leads to a range of products. In the early 20th century, the agro-food industry often extracted only one product from one agro-material (e.g. starch from potato) and regarded the remainder as waste ([van der Padt, 2014](#)). Nowadays, however, more value is created by valorizing the remainder into useful products, for example by obtaining proteins from whey, which was initially discarded as waste from the production of cheese. Different process designs result in product portfolios with different quantities and values of products, and different transportation requirements. The multi-product nature is therefore important when evaluating and comparing food process designs.

The quality of agro-materials and their derived products changes over time. Exposing a product such as milk to increased temperatures for some time severely reduces its keeping quality

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