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Integrated Production Planning and Scheduling for Mass Customization in Food Industry: A Conceptual Framework

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ABSTRACT

The increase of customers' needs and wants will increase the demand of product varieties. This encourages a shift from mass production manufacturing strategy to mass customization (MC). MC Implementation in food industry interested to be studied because raw material and production process in food industry has unique characteristics. Increased product variants due to the application of MC will cause problems in production planning and scheduling. This paper aims to develop a conceptual framework that can be used to study of integrated production planning and scheduling for implementation mass customization in food industry. This conceptual framework is expected to be used to study, guide, and frame into in this area in the future. As literature review are defined as a primarily qualitative analysis, this paper collected papers from journals and sorted by topic and its method of use. The trend of diversification and customization of products require production facilities that can produce multi-product. In addition, the production facilities must be able to respond to fluctuations in customers' demand. Model of integrated production planning and scheduling problem is difficult to solve, especially in the food industry has a distinct characteristic with different production constraints from other manufacturing industries. Character of scheduling problem in food industry include the character in finished product, resources, constrains, and criteria. Therefore, it is necessary to develop a model of integrated MC production planning and scheduling to handle an increase in variation of products.

Keywords: *Food Industry, Framework, Mass Customization, Production Planning, Scheduling*

1. Introduction

Food industry market is very dynamic and highly competitive. There is a very wide range of food industry products in accordance with the diversity of consumer appetites and consumption trends. To face the challenges of the market and adapt to the business processes that always changing the condition and its regulation, then the condition required a new method to monitor production systems are applied [1].

These developments are supported by customers' needs and wants who are changing from time to time. Changes the customers' needs and wants tend to be progressively, in terms of design, quality, and delivery process. Increasingly of customers' needs and wants are demanding the company to be able to produce of varied product. This led to a shift in production strategy of mass production to mass customization.

MC is a production system that uses cost and speed as well as mass production to meet the needs of the product or service individually, or can be said as a production system that combines between mass production and individual demand [2]. According to Silveira et al. [3], MC associated with the company's ability to provide products or services that vary through a flexible process, therefore to implement MC sometimes need to adjust the production process.

This is in line with production pattern in food processing industry that characterized by different product structure, in which a small amount of raw material used to produce various types of the final products according to customer demand [4]. However, the food industry has different characteristics from other manufacturing industries. According to McIntosh et al. [5], there are several factors that distinguish food industry with other manufacturing industries, among which are chemical change, maturing cycles/delay and food product decay. With the existence of these differences, hence the production systems in food industry also possessed of different characteristics.

An increase in the variety of products will affect production planning and scheduling. Review of the integration of the medium term production planning and short term scheduling has been done by Maravelias and Sung [6]. This study present a model approach to integrate production planning and scheduling decisions, as well as problem solving strategies. Tendency towards diversification and customization of products led to a complex production facilities networks. In addition, the production facility must be able to respond to fluctuations in demand. Production planning is also follow a complex operational constraints.

Similarly, in the food industry, the production process can take continuously or batch. In general, the production process can be divided into two stages [4,7–10]. In the first stage, the raw materials are processed to produce an intermediate product, and then performed the process of packaging the finished product. Hence, the scheduling can be a combination of the process of the discrete, continuous and batch, and when coupled with distinct characteristic of food products, such as a high diversity of products (flavor, packaging, labeling, etc.), as well as the complex products formulation, then the scheduling would be a complex problem [11].

2. Method of the Study

The first step in the paper is to conduct a review of the literature. As literature review are defined as a primarily qualitative analysis. Articles sought and collected through the journal online based on research topic, including through Sciencedirect, Tandfonline, Google Scholar and e-books. Keyword that are used are: food industry, mass customization, production planning, and scheduling.

Articles that have been collected are sorted by topic and its method of use. Topics are sorted by using the term, there are: food industry, mass customization (MC), MC in food industry, production planning and scheduling, production planning and scheduling in food industry. While the methods used are sorted by types, namely: case study, experiment, literature review/conceptual/framework, and modeling. The sorting results as shown in Table 1.

Table 1. Sorting articles result by topic areas and methods used

Method	Topic Area				
	Food Industry	*MC*	*MC in Food Industry*	*Production Planning and Scheduling*	*Production Planning and Scheduling in Food Industry*
Case Study	1	1	-	-	1
Experiment	-	1	-	-	-
Literature Review/Conceptual/Framework	3	3	3	3	2
Modeling	5	-	-	2	9

3. Mass Customization in Food Industry

Increased customers' needs and wants will increase the demands of products variety. It is one of the things that encourage a shift manufacturing strategy from mass production to mass customization. The concept of mass customization (MC) was introduced in the late 1980s and followed up with an increase in flexibility and optimization elements of cost and quality [3]. MC is a production system that uses cost and speed as well as the mass production to meet the needs of the products or services individually, or can be said to be a production system that combines mass production and individual demand [2]. According to Silveira et al. [3], MC is related to be ability of the company to provide a product or service through a flexible processes.

The application of mass customization (MC) in food industry has not been studied extensively. There are some research that have been published, which talk about the possibilities of applied concept of MC on the food industry, namely: Matthews et al. [12] investigated about food processing flexibility; Boland [13] discussed about the potential of MC in food industry to meet different nutritional needs at each individual; and McIntosh et al. [5] discussed the issue of related application MC in food industry.

Research on the application of MC in food industry is still lacking. Actually mass customization implementation in food industry is interested to be studied because raw material and production process in food industry has unique characteristics. Raw material in food industry has certain characteristics, namely: seasonality, perishability, and variability [14]. Meanwhile food industry also has differences in production process when compare to other manufacturing industries. McIntosh et al. [5] has identified 13 key factors that differentiate between the food industry production process and other manufacturing industries, namely: chemical change, food product decay; maturing cycles/delay, mixing product and assembling products, recycling/recovery, cleaning/purging, packaging, simplifying product design for MC, access, delicate foodstuffs (handling), legal provisions (sell-by date and others), economics of scale, and distribution.

Production system in food industry, generally involves two stages process, i.e.: processing and mixing. The processing stage, produce intermediate products or semi-finished products. While on mixing stage, blends intermediate products to produce final product [8]. According to Akkerman and Donk [4], the pattern of production in the food industry is characterized by a different product structure, in which a small amount of raw materials used to produce a variety of final products according to customer's demand. Therefore, it becomes impossible or inefficient when producing different kinds of final products are individually. Things are generally done to reduce the effects of various types of products in operational performance in food processing production system is producing some or all of the final product with the blending of a number of intermediate product selected [15], [16]. These pattern is in line with Mass customization concept.

Mass customization (MC) is a production system to meet the needs of the products or services individually with cost and speed close to the mass production, or can be said that a production system that combines mass production and individual demand [2]. MC regards customer satisfaction while maintaining production costs low and high quality products. If the food industry applies the MC concept, the food industry can produce product variants according to customers' need and demand with reasonably low cost.

Therefore, a company that will implement the MC should prepare the production system design to meet these demands. According to Pollard et al. [17], there are several advantages of MC, i.e.: cut cost of inventory and material waste, increase cash flow, shorten time of responsiveness, and ability to supply of products and services with lower cost. There are three main strategies associated with MC namely: manufacturing flexibility, modularization, and postponement [18]. Based on these strategies can be identified the possibility of MC application on certain types of food products as shown in Table 2.

Table 2. Potential for application of MC technique

Strategy	Yoghurt Production [a]	Potato crisp production [a]	Batter based puddings [b]
Modularization	P	Y	P
Manufacturing postponement	N	P	N
Assembly postponement	P	P	P
Packaging postponement	Y	P	-
Labelling postponement	P	P	P
Time postponement	N	Y	-
Place postponement	N	Y	N

P: possibility of application; Y: definite potential for application; N: no potential for application; -: no information
Sources: a : [5]; b : [18]

The possibility of application of the existing strategy would depend on several things, i.e.: the nature of the raw materials, processing, and the properties of the final product. Processing of yoghurt cannot apply manufacturing postponement strategy because it involves fermentation process where the process cannot be put off. Similarly for the time postponement strategy, yoghurt has a relatively short shelf life. Unlike for potato crisp products, the process of making potato crisp can be postponed. In addition, the potato crisp has a relatively long shelf life. The labelling postponement strategy is the most frequently applied strategy for all food production system.

Implementation of MC concept in a company is not easy. There are several key success factors MC application, namely: modular product design, flexible manufacturing process, sophisticated order management, integrated information system, and postponement of assembly [17]. Demand uncertainty is a challenge for MC. If demand is lower than production capacity, it will cause problem. To minimize that problem, delay in operation can be used as an alternative solution, therefore postponement strategy can be used when demand is low. Just consider the operation that can be postponed in a production process.

4. Production Planning and Scheduling

Planning and scheduling is the decision making process used by manufacturing and service industries. This decision making process plays an important role in the process of procurement and production, transportation and distribution, as well as processing of information and communication. Planning and scheduling either on manufacturing or service industries must interact with many functions in the organization. These interaction is usually depends on the system built and sometimes different from one to the other. Scheduling process also interact with the production planning process that handles the medium term planning [19].

To address the challenge of product life cycles are getting shorter and the increasing products complexity required appropriate design, planning and operation of manufacturing network. Coupled with the influence of mass customization and volatility of demand, the company is required to develop the design and network planning as well as manufacturing system holistically. An integrated and harmonized framework to support manufacturing network design, planning, and supervision had been proposed by Mourtzis and Doukas [20]. This framework can support integrated decision making process ranging from the management company to the scheduling on the production floor. In addition it can also integrate material planning with production planning system.

Planning problems includes a broad field, starting from procurement and production to distribution and marketing, as well as for a range of time ranging from long term decision (strategic) to short term decision (operational) [6], as shown in Figure 1. The tendency towards diversification and customization of products, for example in the chemical industry, require production facilities to produce multi product, which often requires a complex process networks. At the same time, the production facility must be able to respond to fluctuations in customer's demand. Models that integrate production planning and scheduling problems are difficult to solve. There are several strategies a settlement that can be classified into three, namely: hierarchical methods, iterative methods, and full-space methods (Figure 2).

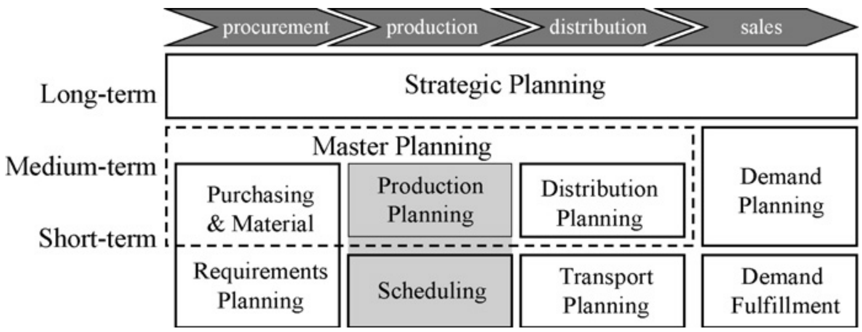

Figure 1. Planning Matrix
(Source: [6]**)**

Problems of production planning and scheduling in the food industry have been studied by previous researchers, among which are [21] and [22]. Kopanos et al. [22] examines the problem of production planning with limited resources in the food industry semi continuous multi products. Issue focused on the packaging stage. This study successfully developed a model of mixed discrete/continuous-time mixed integer linear programming. While Kopanos et al. [21] discusses the production planning and logistics simultaneously for single-site and multi-site on semi-continuous food industry. A model of discrete/continuous-time mixed integer programming was developed based on the products families.

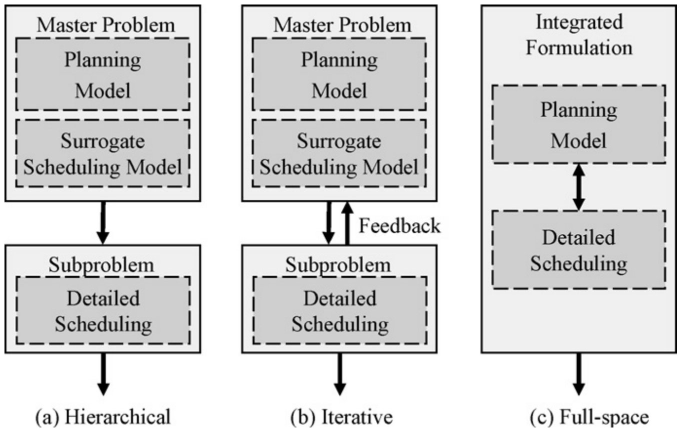

Figure 2. ***Solution strategies for integrated production planning and scheduling***
(Source: [6]**)**

Increased product variants due to the application of mass customization will cause problems in production planning and scheduling. Scheduling problems in the food industry has a distinctive characteristic with production constraints different from other manufacturing industries [1]. Character of scheduling problem in the food industry includes the character in finished product, resources, constraints (e.g. temperature, pressure, processing time, rational speed, etc.) and criteria. The final product of food industry have a release day, a due date, and step of operations, including the number of operations, and requires a set of components and materials. Food industry in general has been using automated equipment, but different materials and components (flavor and color) processed on the same equipment, so it takes cleaning process included in the scheduling. Cyclic scheduling with release dates, due dates and deadlines are also conducted by Shirvani et al. [23].

Constraints that must be considered in the scheduling problem in the food industry is the raw material must be used before expired, each component must be available in sufficient quantity to achieve economic production lot, final product due-dates, and cleanup operation should be optimized because the effect on product quality. Specially another purposes related to the scheduling problem in the food industry are cost or amount of expired products (raw materials, intermediate products, and final products) should be minimized, as well as the intervals of the date of the finished product and the date of the expedition should be minimized [1].

Integrated production planning and scheduling in the food industry especially in yoghurt products have been made by Sel et al. [24]. This paper introduces a multi-echelon, multi-period integrated MILP model with shelf life consideration, furthermore it also discussed about distribution planning, and scope of the problem is shown in Figure 3. Integrated production and distribution planning has been done by Bashiri et al. [25], Fahimnia et al. [26], and Sarrafha et al. [27], and which addresses associated perishable product that are Ahumada et al. [28], and Amorim et al. [29].

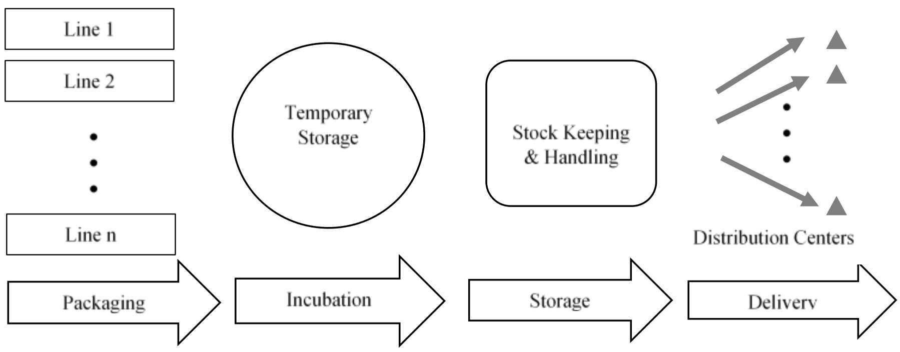

Figure 3. ***Yoghurt production problem***
(Source: [24]**)**

5. Conceptual Framework

Food industry has the potential to be developed cause needs of food will increase and more diverse. The development is supported by the customers' needs and wants are changing from time to time. The changes of customers' needs and wants tend to be more varied, both in term of design, quality, and delivery process. Varied customers' needs and wants are demanding the company to be able to produce a product which varies.

Food industry has to choose appropriate strategy of production systems to meet customers' needs and wants. Literature study suggests different strategies of the production system in the food industry, they are: production planning and scheduling [30–33], MTS-MTO strategy [4,15,31], the concept of decoupling point [4], the concept of postponement [5], as well as the application of mass customization (MC) related issue in the food industry. So far the study of the application of MC concept on food industry has not been applied extensively. Therefore, it is necessary to research about the possibility of the application of MC on the food industry.

Dong et al. [34] has reviewed the MC implementation in the garment industry. This paper states that the method to solve the problem by providing modules and standard products. Semi-finished products are manufactured with the mass production concept. At this stage, the key success factor for the company is to keep production costs to be reduced as low as possible. In the next stage, form of customized products tailored to customers' needs.

Although the application of the concept of mass customization in the food industry needs to be examined more thoroughly, not all production systems in the food industry can implement the MC concept. The implementation of MC concept in food industry depends on the characteristics of the raw material, processing and the final products, as well as the customers' needs and wants. Improved product variants will cause production planning and scheduling problems. Moreover, the food industry has different characteristics, mainly related to specific processes character and properties of perishables products. Research related to production planning and scheduling in the food industry has been done, but not yet integrated and embodies the concept of MC.

Overall based on the literature study compiled the conceptual framework as shown in Figure 4. An important element in the successful implementation of mass customization is customers' needs and demand. Identify customers' needs and demand, detail stages of the production process, and its response to the customer' needs and demand acquired through case study. At this stage will be conducted product families and customizability analysis. Result of case study is used to determine the level and strategy of MC to be applied. Next stage will be mathematic model related of integrated production planning and scheduling to handle increased product variety by consider characteristics of demand, raw materials, finished products and productions processes in the food industry.

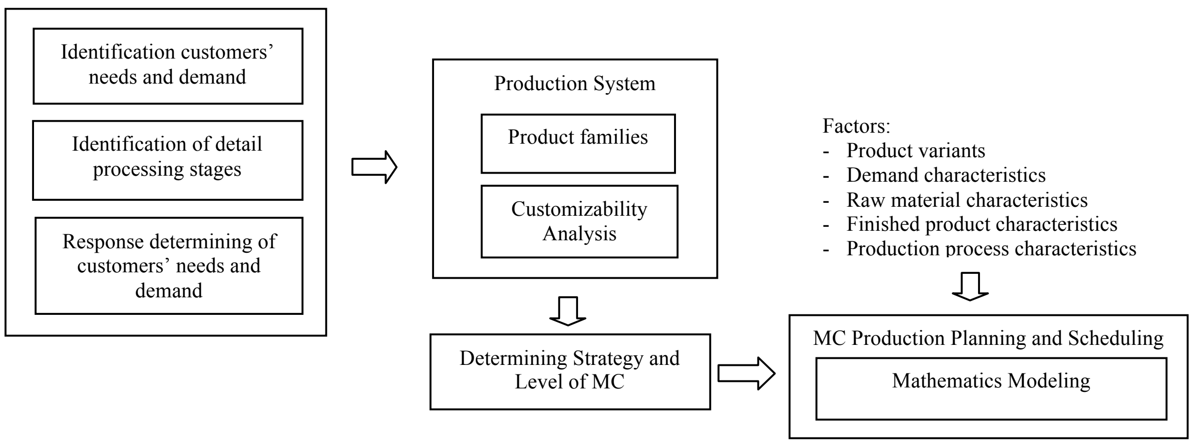

Figure 4. Conceptual framework

6. Conclusion

Application of mass customization concept in the food industry needs to be examined more thoroughly. Not all production systems in the food industry can implement the MC concept, depending on the characteristics of the raw material, processing and the final products, as well as the customers' needs and wants. Improved product variants will cause production planning and scheduling problems.

This important thing to consider in assessing the possibility of applying the MC concept in a production system is identification of customers' needs and demand, as well as the ability of the production system in response to customers' needs and demand. Product families and customizability analysis can be used to determine the strategy level of MC that would be applied to a production system.

Studies related to integrated production planning and scheduling has been done, but not yet embody the concept of MC in particular in the food industry that have a distinctive character of raw material, finished product, and production processes, for example related to release dates, due dates, and deadlines, as well as shelf life. It also should be considered for a cleanup operation when the same production facilities are used to produce different product variants. This framework is expected to be a reference to conduct a study regarding the model development of integrated production planning and scheduling for the implement MC concept in food industry.

7. References

[1] E. Gargouri, S. Hammadi, and P. Borne, "A study of scheduling problem in agro-food manufacturing systems," *Mathematic and Computers in Simulation*, vol. 60, 2002, pp. 277–291.

[2] X. Xu, "Position of customer order decoupling point in mass customization," in *Proceedings of the Sixth International Conference on Machine Learning and Cybernetics*, August 2007, pp. 19–22.

[3] G. Da Silveira, D. Borenstein, and H. S. Fogliatto, "Mass customization: Literature review and research directions," *International Journal of Production Economics*, vol. 72, no. 49, 2001, pp. 1–13.

[4] R. Akkerman and D. P. Van Donk, "Product mix variability with correlated demand in two-stage food manufacturing with intermediate storage," *International Journal of Production Economics*, vol. 121, no. 2, 2009, pp. 313–322.

[5] R. I. McIntosh, J. Matthews, G. Mullineux, and a. J. Medland, "Late customisation: issues of mass customisation in the food industry," *International Journal of Production Research*, vol. 48, no. 6, 2010, pp. 1557–1574.

[6] C. T. Maravelias and C. Sung, "Integration of production planning and scheduling: Overview , challenges and opportunities," *Computers and Chemical Engineering*, vol. 33, 2009, pp. 1919–1930.

[7] R. Akkerman and D. P. Van Donk, "Product prioritization in a two-stage food production system with intermediate storage," *International Journal of Production Economics*, vol. 108, 2007, pp. 43–53.

[8] R. Akkerman, D. van der Meer, and D. P. van Donk, "Make to stock and mix to order: choosing intermediate products in the food-processing industry," *International Journal of Production Research*, vol. 48, no. 12, 2010, pp. 3475–3492.

[9] R. Akkerman, D. P. Van Donk, and G. Gaalman, "Influence of capacity- and time-constrained intermediate storage in two-stage food production systems," *International Journal of Production Research*, vol. 45, no. 13, 2007, pp. 2955–2973.

[10] O. a. Kilic, R. Akkerman, D. P. van Donk, and M. Grunow, "Intermediate product selection and blending in the food processing industry," *International Journal of Production Research*, vol. 51, no. 1, 2013, pp. 26–42.

[11] T. Wauters, K. Verbeeck, P. Verstraete, G. Vanden, and P. De Causmaecker, "Real-world production scheduling for the food industry: An integrated approach," *Engineering Applications of Artificial Intelligence*, vol. 25, no. 2, 2012, pp. 222–228.

[12] J. Matthews, B. Singh, G. Mullineux, and T. Medland, "Constraint-based approach to investigate the process flexibility of food processing equipment," *Computers and Industrial Engineering*, vol. 51, 2006, pp. 809–820.

[13] M. Boland, "Innovation in the food industry: Personalised nutrition and mass customization," *Innovation: Management, Policy & Practice*, vol. 10, no. 1, 2008, pp. 53–60.

[14] J. E. Austin, "Agroindustrial project analysis," EDI Series in Economic Development, The Johns Hopkins University Press Baltimore and London, 1983.

[15] D. P. Van Donk, "Make to stock or make to order: The decoupling point in the food processing industries," *International Journal of Production Economics*, vol. 69, 2001, pp. 297–306.

[16] C. A. Soman, D. P. Van Donk, and G. Gaalman, "Combined make-to-order and make-to-stock in a food production system," *International Journal of Production Economics*, vol. 90, 2004, pp. 223–235.

[17] D. Pollard, S. Chuo, and B. Lee, "Strategies for mass customization," *Journal of Business & Economics Research*, vol. 6, no. 7, 2008, pp. 77–86.

[18] J. Matthews, R. McIntosh, and G. Mullineux, *Constasting opportunities for mass customization in food manufacture and food process, In Fogliatto, F.S. & da Silveira, G.J.C. (ed.). Mass customization: Engineering and managing global operations. Springer*. 2011.

[19] M. L. Pinedo, *Planning and Scheduling in Manufacturing and Services*. New York USA: Springer Science+Business Media, Inc., 2005.

[20] D. Mourtzis and M. Doukas, "Design and planning of manufacturing networks for mass customisation and personalisation: Challenges and Outlook," *Procedia CIRP*, vol. 19, 2014, pp. 1–13.

[21] G. M. Kopanos, L. Puigjaner, and M. C. Georgiadis, "Simultaneous production and logistics operations planning in semicontinuous food industries," *Omega*, vol. 40, no. 5, 2012, pp. 634–650.

[22] G. M. Kopanos, L. Puigjaner, and M. C. Georgiadis, "Resource-constrained production planning in semicontinuous food industries," *Computers and Chemical Engineering*, vol. 35, no. 12, 2011, pp. 2929–2944.

[23] N. Shirvani, R. Ruiz, and S. Shadrokh, "Cyclic scheduling of perishable products in parallel machine with release dates, due dates and deadlines," *International Journal of Production Economics*, vol. 156, 2014, pp. 1–12.

[24] C. Sel, B. Bilgen, J. M. Bloemhof-ruwaard, and J. G. A. J. Van Der Vorst, "Multi-bucket optimization for integrated planning and scheduling in the perishable dairy supply chain," *Computers and Chemical Engineering*, vol. 77, 2015, pp. 59–73.

[25] M. Bashiri, H. Badri, and J. Talebi, "A new approach to tactical and strategic planning in production – distribution networks," *Applied Mathematical Modelling*, vol. 36, no. 4, 2012, pp. 1703–1717.

[26] B. Fahimnia, R. Zanjirani, R. Marian, and L. Luong, "A review and critique on integrated production – distribution planning models and techniques," *Journal of Manufacturing Systems*, vol. 32, no. 1, 2013, pp. 1–19.

[27] K. Sarrafha, S. Habib, A. Rahmati, S. Taghi, A. Niaki, and A. Zaretalab, "A bi-objective integrated procurement , production, and distribution problem of a multi-echelon supply chain network design : A new tuned MOEA," *Computers and Operations Research*, vol. 54, 2015, pp. 35–51.

[28] O. Ahumada, J. R. Villalobos, and A. N. Mason, "Tactical planning of the production and distribution of fresh agricultural products under uncertainty," *Agricultural Systems*, vol. 112, 2012, pp. 17–26.

[29] P. Amorim, H.-O. Gunther, and B. Almada-lobo, "Multi-objective integrated production and distribution planning of perishable products," , *International Journal of Production Economics*, vol. 138, 2012, pp. 89–101.

[30] R. Simpson and A. Abakarov, "Optimal scheduling of canned food plants including simultaneous sterilization," *Journal of Food Engineering*, vol. 90, 2009, pp. 53–59.

[31] K. Rajaram and U. S. Karmarkar, "Campaign planning and scheduling for multiproduct batch operations with applications to the food-processing industry," *Manufacturing & Service Operations Management*, vol. 6, no. 3, 2004, pp. 253–269.

[32] C. A. Ã. Soman, D. P. Van Donk, and G. J. C. Gaalman, "Capacitated planning and scheduling for combined make-to-order and make-to-stock production in the food industry: An illustrative case study," *International Journal of Production Economics*, vol. 108, 2007, pp. 191–199.

[33] M. Lütke entrup, H.-O. Günther, P. Van Beek, M. Grunow, and T. Seiler, "Mixed-Integer Linear Programming approaches to shelf-life-integrated planning and scheduling in yoghurt production," *International Journal of Production Research*, vol. 43, no. 23, 2005, pp. 5071–5100.

[34] B. Dong, H. Jia, Z. Li, and K. Dong, "Implementing mass customization in garment industry," *Systems Engineering Procedia 3*, 2012, pp. 372–380.

