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A survey on metaheuristics for optimization in food manufacturing industry

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ABSTRACT

This paper surveys recent articles on the applications of metaheuristics for solving optimization problems in the food manufacturing industry. Metaheuristics for decision making has attracted significant research and industry attention due to the increasing complexity of models and quick decision making requirements in the industry. Metaheuristics have been applied to food processing/production technologies including fermentation, thermal drying and distillation and other system wide optimization such as transportation, storage (warehousing), production planning and scheduling. In terms of metaheuristics algorithms, Genetic Algorithm and Differential Evolution are the most popular while other algorithms have also demonstrated their effectiveness in addressing various optimization problems. Most problems were typically formulated as single objective mathematical models constructed from experimental or collected data. Recently, multi-objective optimization is becoming more popular because it is able to consider problems from several perspectives and attain more practical results.

1. Introduction

Companies make numerous optimization decisions in a competitive and dynamic environment every day. They adopt different methodologies ranging from trial-and-error to highly complex mathematical models and algorithms. In the food manufacturing industry, optimization decisions are frequent and becoming more complex with the current technological advances. The cause for the increasing complexity can be attributed to the increased number of variables under consideration and the hardness/complexity of objective functions that guide the optimization [44]. Metaheuristic approaches allow decision makers to obtain near optimal results within a relatively shorter period of time [108]. Academically, these approaches contribute to the literature on the development of novel or improved solution procedures for food processing.

Real world problems, modeled as optimization problems, consist of three parts: Variables/Design Vector—factors that need optimization, Objective(s)—a target function (either minimization or maximization), and Constraints—conditions that limit the objective(s) [92]. Then metaheuristics may be applied to search for the best solution. In general, metaheuristics are defined as search methodology or algorithms of a solution space for a near optimal solution to an optimization problem [108]. Factors that affect the quality of the search result include the type of problem model, applied metaheuristic algorithm, size of the search space, time allocated for the search, and computer capacity.

Banga et al. [12] presented a summary of Evolutionary Computation and Simulating Annealing metaheuristics optimization methods for the food processing engineering. The authors presented the application of these metaheuristics in the optimization of thermal, drying, contact cooking, microwave heating and other processing technologies. Erdogdu [38] has presented papers that demonstrated the use of Tabu Search and Genetic Algorithm (GA) for optimization in food engineering. As a compilation of different publications, Erdogdu presented the application of these metaheuristics approaches in food engineering. Application areas include thermal processing, vehicle routing and heat exchangers design. In a more recent work, Enitan and Adeyemo [37] reviewed research papers in food processing industries that adopted Evolutionary Algorithms (GA, Differential Evolution (DE) and their hybrids with other techniques). The applications include thermal processing, food quality, process design, drying, fermentation and hydrogenation processes. As discussed in a later section, these two algorithms, GA and DE, are widely used but we note that other algorithms have proven to be quite as effective and in some cases better in terms of the best result attained and run time required. Broader range of metaheuristics approaches were presented to show the

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Table 1
Summary of papers.

		Application area	
		Processing operation optimization	System optimization
Single solution			
Local Optima Search		Dholvitayakhun and Kluabwang [32], Bouraoui et al. [17], Simpson et al. [103], Torrecilla et al. [113]	
Random Search		Abakarov et al. [1], Simpson et al. [102]	Pacheco et al. [88]
Simulated Annealing		Wei-zhong and Xi-Gang [125], Wei-zhong et al. [142], Russo et al. [97]	
Tabu			Rochat and Semet [96], Osvald and Stirn [87], Zhang et al. [134]
Population based			
Ant Colony		Tang et al. [110]	Xiaowei et al. [127], Sprenger and Mönch [104], Gong and Fu [50], Hecker et al. [57]
Differential Evolution	DE	Oonsivilai and Oonsivilai [86], Garlapati and Banerjee [48], Bhattacharya et al. [16], Ceric and Kurtanjek [20], Mariani et al. [70], da Silva et al. [29,95]	
	HDE	Chiou and Wang [26,25], Wang and Cheng [120], Wang et al. [121], Liu and Wang [68]	
Genetic Algorithm	GA	González-Sáiz et al. [53], Nougués et al. [83], Angelova et al. [7,8], Hashemi Shahraki et al. [56], Yuzgec et al. [131], Aghbashlo et al. [2], Massebeuf et al. [71], Jaya Shankar and Bandyopadhyay [60], Tumuluru et al. [114], Fraga and Senos Matias [45], Benvenga et al. [15], Zahedi et al. [133], Silroy et al. [101], Olmos et al. [85]	Mure [80], Heinonen and Pettersson [58], Yao and Huang [128], Amorim et al. [5], Li and Li [66], Karray et al. [61], Shaw et al. [99], Dacal-Nieto et al. [30], Phaisangittisagul [90], Komany-Zareh [64], Sukstrienwong [107], Wu et al. [126], Validi et al. [117], Wang [122], Validi et al. [116], Dai et al. [31], Costa [28]
	GA and NN	Zuo and Wu [139], Chen and Ramaswamy [23], Nagata and Chu [82], Baishan et al. [10], Erenturk and Erenturk [42], Koc et al. [63], Chen and Ramaswamy [22], Chen et al. [24], Mohebbi et al. [75], Yuzgec et al. [132], Banooni et al. [13], Goni et al. [52], Garcia-Gimeno and Hervas-Martinez [47], Haider et al. [55], Tao et al. [111], Ziguang et al. [137], Wee et al. [123], Ying et al. [129], Fathi et al. [43], Mohebbi et al. [76], Shekarchizadeh et al. [100], Izadifar and Jahromi [59]	Morimoto et al. [78,79], Mohebbi et al. [73], Ahmad et al. [3], Doganis et al. [33]
	GA & Fuzzy Logic	Vradis and Floros [119], Perrot et al. [89], Mohebbi et al. [74]	Freisleben and Strelen [46], Zhou and Gu [136]
	GA & MLR	Casoni and Sarbu [19]	
Particle Swarm		Liu et al. [67], Amiryousefi et al. [4], Vitor and Gomes [118]	Gong et al. [51], Zhao and Dou [135], Tang and Yan [109], Govindan et al. [54]
Others	ABC	Choon et al. [27]	Behzadi et al. [14], Banerjee [11]
	AFS	Men [72]	
	BA & FA	Yeomans [140], San Chua et al. [141]	

MLR—Multivariate Linear Regression, ABC—Artificial Bee Colony algorithm, AFS—Artificial Fish School.

overall applications of these approaches in the industry incorporating the latest trends.

This paper surveys publications on the application of metaheuristics based on classifications from literatures for the food manufacturing industry to understand better the specific implementation of each approach in the industry. It aims to: (1) survey and present various research papers on a range of metaheuristic application approaches in food manufacturing industry, (2) organize and classify research papers to better match metaheuristic approaches and their application areas with food manufacturing processes and systems, (3) discuss the main function of the specific metaheuristic approaches employed, and (4) show research trend.

In this survey, papers are presented under two general groups: single-solution based (work only on one solution at a time) and population based (work on multiple solutions at a time) [108,18,49]. In each group, optimization problems that focused on production processes or product development are classified as Processing Operation Optimization whereas those involved the whole manufacturing system, such as logistic, planning and scheduling, are categorized as system optimization. We consider the food manufacturing industry as all industries engaged in processing/producing food for humans and animals, including medicinal and supplement products.

The rest of the paper is organized as follows. Sections 2 and 3 present algorithms and research works in single-solution and population based approaches, respectively (summarized in Table 1, detailed in Appendix A). Section 4 analyzes the applications of the approach and presents observed trends. Concluding remarks are presented in the last section.

2. Single-solution metaheuristics

Single-solution metaheuristic algorithms search for the optimal solution by taking and analyzing one solution at a time [108]. The search is carried out by testing local neighborhood for the optimal solution (known as exploitation) for all neighborhoods in the search space (known as exploration). The formulation of the problem defines the search guiding rules such as Neighborhood—rule for considering two solutions as neighbors, Termination Condition—criteria for ending the search, and Evaluation Function—rule for measuring the quality of a solution. Four common metaheuristics, Local Optima Search Method, Random Search, Simulated Annealing and Tabu Search, were identified during the survey and will be discussed in this section.

2.1. Local Optima Search Method

This method searches for local optima by iteratively evaluating a solution based on an objective function till some termination condition is met. Dholvitayakhun and Kluabwang [32] adopted a simple local optima search algorithm for an assignment problem in nutrition. In their paper, an energy balance function (daily energy