RESEARCH ARTICLE OPEN ACCESS

Quality and Operations Management in Food Supply Chains: A Literature Review

[1]amaresh Satapathy, [2]shubham Kumar Ojha,
Gandhi Institute of Excellent Technocrats, Bhubaneswar
Sidhartha Institute of Engineering & Technology, Koraput, Odisha, India

Wepresentaliteraturereviewonqualityandoperationsmanagementproblemsinfoodsupplychains.Infoodindustry,the quality of the food products declines over time and should be addressed in the supply chain operations management. Managing food supply chains with operations management methods not only generates economic benefit, but also contributes to environmental andsocialbenefits.Theliteratureonthistopichasbeenburgeoninginthepastfewyears.Since2005,morethan100articles have beenpublishedonthistopicinmajoroperationsresearchandmanagementsciencejournals.Inthisliteraturereview,weco ncentrate on the quantitative models in this research field and classify the related articles into four categories, that is, storage problems, distributionproblems,marketingproblems,andfoodtraceabilityandsafetyproblems.Wehopethatthisreviewservesasa reference forinterestedresearchersandastartingpointforthosewhowishtoexploreitfurther.

I. INTRODUCTION

Foodquality,includingsafety,hasbeenamajo rconcernfaced by the food industry, partly due to a series of food safety crises and scandals [1]. Quality of the food products contin- uously changes as they move along the supply chain, which can lead to significant social, economic, and environmental consequences.

Food spoilage is one of the major issues related to food safety and quality. When food products move from farms to food processors, food retailers, and end customers, spoilage cannotbeavoided.Foodperishabilitymaycausehugew astes. ItisestimatedbytheUnitedNationsthatapproximatelyo ne- third of all food produced for human consumption iswasted each year. In other reports, 40% of total production was wasted[2,3].Theeconomiclosscausedbyfoodperisha bility and waste reached $218 billion in the US, $143 billion in Europe, and $27 billion in Canada [4–6]. In addition to the economicimpacts,foodperishabilityalsocausedfoods afety problemsinmanyregions.AccordingtotheWHO[7],a bout 600millionpeoplebecameillafterconsumingcontami nated

foodeachyear.Amongthem420,000died,inc luding125,000 children under the age of five years. This has raised serious concern about food safety in manycountries.

The improvement of preservation technologies has pro- vided many tools to reduce waste and improve safety in food supply chains. Many extensive literature reviews have been conducted on preservation and traceability technology adoptions in food supply chains. For example, Mercier et al. [8] provided a comprehensive literature review on time-temperature management along the food supply chain. Badia-Melisetal.[9]reviewedtraceabilitytechnologyadop- tionsinfoodsupplychains.Theadoptionofvarioustem per- ature control or traceability technologies allows information to be gathered to optimize inventory decisions, distribution decisions, and retail strategy even enhance safety in food supplychains.

Also, the research progress in operations management provides many opportunities for companies to reduce prod- uct waste due to decaying and to enhance food quality. Akkerman et al. [10] reviewed the quantitative operations management research on food distribution concerning food

TABLE1:Searchingguidelinesandresults.

Filtertype Descriptionsandguidelines Results

Articles that were identified in the database search or appeared in the reference lists of one of the selected articles

(i) Topic:articlesthatdeveloporapplyquantitativemodelsonfoodqualityandoperations

Inclusion criteria

Keywords

Keywords search

management in food supply chain

(ii) Language: limited toEnglish

(iii) Time span:2005–2017

(iv) Paper type: academic (peer-reviewed) journalarticles

(i) GroupAkeywords:“foodquality”,“perishablefood”,and“perishableproducts”

(ii) GroupBkeywords:“operationsmanagement”,“inventorymanagement”,“marketing”, “customer behaviors”, “supply chain coordination”, “production planning”, “quality control”, and“distribution”

(i) Selectedonlinedatabases(e.g.,Elsevier,WileyOnline,Informs,Springer,andHindawi)

(ii) Allselectedarticlescontainatleastonekeywordcombinationfromgroups AandBin the title, abstract, or list ofkeywords

426

Exclusion criteria

(i) Not related to foodquality

(ii) Not related to the operationsmanagementproblems 105left

(iii) Not using the quantitativemethodologies

quality, food safety, and sustainability. In this article, we mainly concentrate on the quantitative operations manage- mentmodelsrelatedtofoodqualitymanagement.Thegoalis topresentthelatestresearchdevelopmentinthisfieldandto identify future researchopportunities.

Assuch,weproposethefollowingtworesearchquestions:

(1) what are the state-of-the-art development and trends in quantitativeoperationsmanagementresearchregardingfood quality management? (2) What gaps exist in the current research, and what are the potential future research oppor- tunities?

This paper is organized as follows: Section 2 presents the methodology of this research along with a descriptive analysis of the existing studies. Section 3 provides details of operations management problems and related research along the food supply chain, including storage, distribution, marketing, and traceability optimization. Section 4 is about the research implications and directions for future research. Section 5 discusses the conclusions and limitations of thisreview.

Methodology

To address the research questions, the study reviews the literature of food quality management in supply chains.

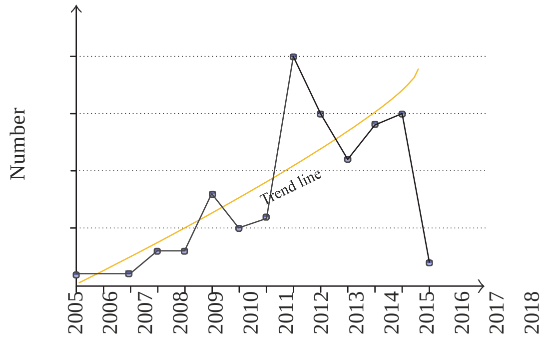
Data Collection. The study aims to review published peer-reviewed articles in the targeted area from 2005 to 2017.Articlesarecollectedfromseveraldatabases,including Elsevier,WileyOnline,Informs,Springer,andHindawi.The search was conducted based on the combination of two categories of key words; one is related to food quality and the other is related to operations management. An example ofsuchkeywordcombinationwouldbe“Inventory”+“food quality”;anotherwouldbe“distribution”+“perishablefood”. Using such kind of keywords search in the databases, we found 426 articles intotal.

20

15

10

5



Year

FIGURE1:Distributionofarticlesovertime.

Relevant Literature and Classification. In this stage, all articles were prudently reviewed. The searching guidelines and results are presented in Table 1. An article was removed from this study if it was not related to food quality, opera- tions management, or not using quantitative methods. The remaining publications were then classified according to a conceptualframeworkproposedinSection3.1.

JournalStatistics.Thenumberofpublications indifferenttimeperiodsispresentedinFigure1toshowtheevolutionofresearchinterestinthistopic.Between2005and 2017, therewereatotalof105articlesontheoperationsmanagementrelatedtofoodqualityinfoodsupplychains.Thenumberofthearticlesisratherlimitedbeforetheyear2008.Thenthenumberrisesslowlyfrom2008to2012.Since2012,scholarshavebecomemoreinterestedinthistopic.Thestatisticsshowthatwhilethetotalnumberofresearchinthisareaisstillsmall,interestinthisfieldhasgrown rapidlyinrecentyears.Figure 2 presents the distribution of articlesinthesemajorpublicationoutlets.The105articlesincludedinthisstudywerepublishedinmorethan30journalsonoperations

International Journal ofProductionEconomicsProduction andOperationsManagementInternational Journal of ProductionResearch
Omega
European Journal ofOperationalResearchComputers & IndustrialEngineering
ORSpectrumBiosystemsEngineeringAnnals of OperationsResearch
AppliedMathematicalModellingMathematical Problems inEngineering
ManagementScienceOperationsResearchJournal of FoodEngineering
Computers & OperationsResearch
OperationalResearch
FoodControlInternational Journal of Mathematics in OperationalResearch

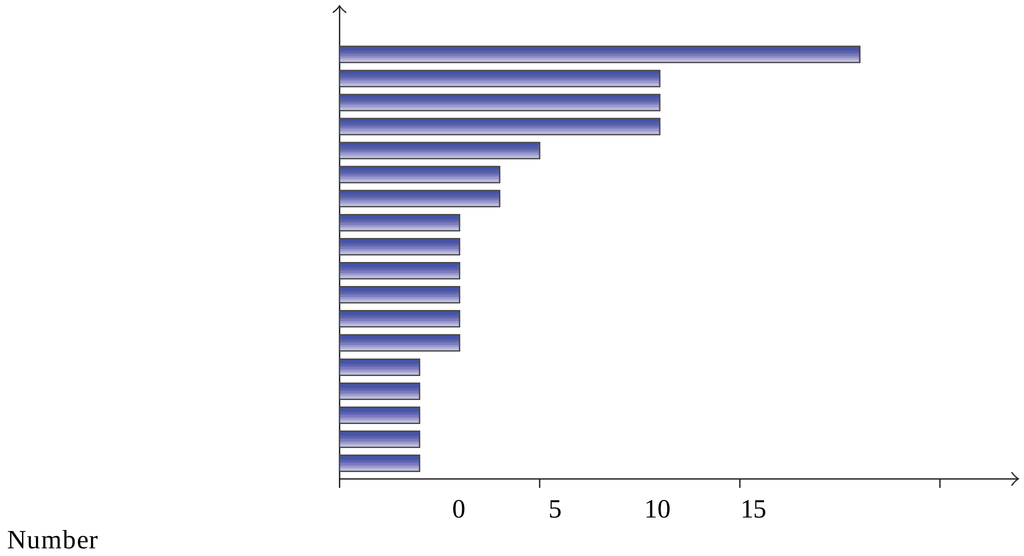


FIGURE2:Distributionofjournals(withnumberofarticles≥2).

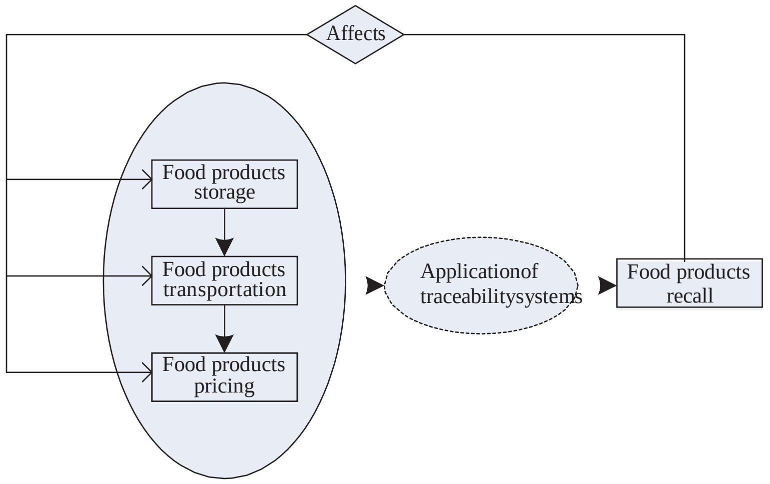


FIGURE3:Conceptualframework.

management or food quality. Apparently, the top journals areInternationalJournalofProductionEconomics(IJPE), Production and Operations Management (POM),Interna- tionalJournalofProductionResearch(IJPR),andOmega, whichaccountforaboutone-thirdofthetotalamount.The first half of the papers contributes to about 80 percent of thetotalpapers.Aftercarefullyreadingthe105articles,we foundthatthesepapersrepresentanappropriateoverviewof thecurrentstate-of-the-artresearchintheareaofoperations managementandfoodqualitycontrolinfoodsupplychains.

Analysis

In this section, quality and operations management prob- lems in food supply chains are discussed in detail. More specifically,wediscussthemainissueswithregardtorelated operations management problems, followed by a discussion of researchchallenges.

Conceptual Framework. In order to identify the progress and gaps in the existing literature on food quality and operations management models, a conceptual framework is constructedtounderstandthekeydecisions,asshownin Fig- ure3.Theframeworkhelpsusunderstandtheachievements, challenges,andopportunitiesintheresearchonfoodquality and operations managementmodels. Section3.2summarizesthestudiesofinventoryproblems with preservation investment, followed by Section 3.3 on transportation planning problems in food supply chains. Next, Section 3.4 covers research on marketing strategies consideringfoodqualityandcustomers'preferences.Lastly, Section3.5presentsthemodelspertainingtofoodtraceability and food recallstrategies.

Inventory Planning with Preservation Investments. A lot of researches deal with inventory management ofperishable products,wheretheirproductionordistributionplanning

is based upon an exogenous perishable rate. For example, fruits in supermarkets will perish in the selling period until they are not safe to eat. However, with the development of preservationtechnologies,theproducts'perishabilitycanbe reduced by making investment in equipment, production processes, and so on. In other words, the perishable rate highlydependsonnotonlythenaturalperishableratelargely determined by environmental factors (such as temperature, humidity, light, oxygen content, and microbial content) but also the preservation technology used in the warehouse and transportationvehicles.

Although the perishing process for food products is natural and cannot be stopped, it can be slowed down by specializedequipment,suchasrefrigeratorsandhumidifiers, to make temperature low and humidity suitable for certain fruits.Hence,itispracticalandimportanttoconsiderinven- torydecisionswithpreservationtechnologyinvestmentdeci- sion.Enterprises'preservationinvestmentisoftencombined withotherdecisions,likepricingorreplenishmentdecisions. Thegoalistomaximizethetotalprofitorminimizethetotal cost by finding an optimal set of preservation investment level, price, or orderingquantity.

Single Level Supply Chain Inventory Models. Some studies focus on a single firm's preservation and inventory decisions. Hsu et al. [11] first developed an analytical Eco- nomic Ordering Quantity (EOQ) model considering both orderingpoliciesandpreservationinvestmentforperishable products. Under the assumption that the deterioration rate is exponentially linked to the investment level, they proposed a method to determine the optimal replenishment cycle, shortage period, order quantity, and preservation technology cost so as to maximize the total profit per unit time. Numericalexampleswerepresentedtoobtainfurtherresults. Lee and Dye [12] extended the model of Hsu et al. [11] by assuming that market demand is linked to inventory levelandshortagesareallowedandpartiallybacklogged.An algorithmwasalsoproposedtosolvetheoptimizationmodel and determine the optimal replenishment and preservation technologyinvestment.

Dye and Hsieh [13] assumed that the deterioration cost is associated with both the preservation investment and the time instance. The objective is to find the opti- mal replenishment and preservation technology investment strategies while maximizing the total profit per unit time overtheinfiniteplanninghorizon.Dye[14]assumedthatthe deteriorationrateisnoninstantaneousandcontrollable.The generalizedproductivityofinvestedcapital,deterior ation, andtime-dependentpartialbackloggingrateswereusedto modeltheinventorysystem.Theuniquenessofthegl obal maximizationwasprovedusingfractionalprogram ming.

Chen and Dye [15] proposed a finite time horizon inventory and preservation investment model, in which the preservation investment can be different in each replenish- ment cycle. They utilized particle swarm optimization to solvethenonlinearprogrammingproblem.HeandHua ng [16] studied the optimal preservation, pricing, and ordering decisions for a kind of seasonal products. Hsieh et al. (2013) formulated an Economic Production Quantity(EPQ) modelfordeterioratingitemswithtime-varyingdemandand controllable deterioration rate in a limited time horizon. A particle swarm optimization approach was also employed to solve the nonlinear programmingproblem.

SinghandSharma[17]studiedaninventorymodelwi th ramp-typedemandrate,controllabledeteriorationrate,and two-level trade credit, in which shortages were allowed and partially backlogged. Bardhan et al. [18] also studied an inventory problem with preservation investment for noninstantaneousdeterioratingproducts.Theystudi edtwo modelsdependingontheon-handstockfinishtime:before and after the deterioration starts. Yang et al. [19] intro-ducedthecreditperiodtheoryintoinventorymodels with preservationinvestmentdecisions.Theystudiedaret ailer selling perishable products to customers and offering a credit period to its customers to buy the products. They established a model to determine the optimal trade credit periods,preservationtechnologyinvestment,andor dering strategiesthatmaximizethetotalprofitoverafinitepl anning horizon.

Unlike previous studies, Dye and Yang[20]treated the selling price as a decisions variable. They considered customers' reference price behaviors and proposed a joint dynamic pricing and preservation technology investment model for a perishable inventory system with time- and price-sensitive demand. Theoretical results were obtained to demonstrate the existence of an optimal solution for the inventoryproblem.Asimpleiterativealgorithmwasuti lized to solve the proposed model by employing the theoretical results.Featuresoftheproposedmodelwereillustrated with sensitivityanalysis.

Kouki et al. [21] extended the known (r, Q) inventory modelsbyassumingproductsareperishable.Theystudi edthe impacts of the application of Time Temperature Integrator (TTI) technology on the inventory management decisions. The TTI technology enables firms to accurately monitor products' freshness and gives information on products' remainingshelflives.Zhangetal.[22]studieddynamic ser- vice investment problem simultaneously with preservation investment for perishable products. The analytical solution for dynamic service investment was obtained under the givensalesprice,preservationtechnology,andreplenis hment cycle by solving an optimal control problem. The impact of common resource constraint on the optimal investment policywasinvestigated.Theyfoundthatforarelativelyl ow common resource capacity, the firm prefers to invest in service improvement rather than preservation technology. Mishra [23] studied an EPQ problem considering uncertain and controllable deterioration rate. Following Day andYang (2016), Mishra et al. [24] studied an inventory model that considers demand rate as a function of stock and selling price. They established an EOQ model considering preser-vation investment, product deterioration, and two types of backordering scenarios. Li et al. [25] studied an inventory controlproblemconsideringtheoptimalpackagingdec isions toextendtheproductshelflife.Highqualitypackagingh elps to better preserve the products but leads to higher costs for sellers.Thegoalistominimizethetotalcostsbychoosin gan appropriate packagingstrategy.

TwoLevelSupplyChainInventoryModels.T hepreser-vationinvestmentproblemhasalsobeenstudiedintwo-level supplychains.Tayaletal.[26]developedatwo-levelsupply chain model, in which the products are perishable and the deteriorationrateiscontrollable.Also,customers'dem andis sensitive to the products' expiration rate. Zhang et al. [27] studied a two-level inventory model for deteriorating items with controllable deterioration rate and price-dependent demand. They derived the optimal decisions for both the decentralized and the centralized models. They found that thetwo-levelsupplychaincanbecoordinatedwitharevenue sharing and cooperative investment contract. The results show that only when the revenue sharing rate lies roughly between 1/2 and 3/4 can the contract perfectly coordinate supply chains in most cases, which has an important impli- cationinsupplyingchaincoordinationofdeterioratingi tems with preservation investment. Shah et al. [28] studied an inventory model in a two-level supply chain consisting of a manufacturer and a retailer. The manufacturer offers a trade credit to the retailer and the retailer's deterioration rate is timedependentandlinkedwithpreservationinvestmen t.The retailer also offers partial trade credit to the buyers. Giri et al.[29]studiedatwo-levelsupplychainmodelwithproduct deterioration, controllable deterioration rate, and unreliable production.

Multiple Facility Inventory Models. Researchers also considered the preservation investments for a multifacility supply chain. Cai et al. [30] studied the optimal ordering policyandfreshproductkeepingeffortsinamultilevels upply chain with long transportation distance and high deteri- oration rate for intransit products. Yu and Nagurney [31] developed a network-based food supply chain production modelunderoligopolisticcompetitionandperishabilit y,with a focus on fresh produce. The product differentiation is characterized by the different product freshness and food safety concerns, as well as the evaluation of alternative technologiesassociatedwithvarioussupplychainactiv ities.

Tsao[32] studied a joint model considering location, inventory, and preservation decision-making problem for noninstantaneous deteriorating items under delay in pay- ments. In the author's model, an outside supplier provides a credit period to the wholesaler that has a distribution system with distribution centers. The goal is to determine the locations, the number, the replenishment time of the distribution centers, and the preservation investments.Tsao
[33] studied the network design problems in a supply chain includingdistributioncentersandretailersconsidering trade credit arrangements, preservation investment, and product deterioration. The goal is to determine the optimal locations ofdistributioncenters,assignmentofretailerstodistrib ution centers, replenishment time, and preservation investment to maximize the totalprofit.

Summary. In this subsection, the inventory problems combined with food preservation investment is presented. We classify the existing papers into three categories for different supply chain structures, that is, single level sup- ply chain, two-level supply chain, and multilevelsupplychain. The research contributions are presented in each part.

TransportationPlanningforPerishableProdu cts.Inthis subsection, we discuss the transportation planning in food supplychainsconsideringfoodqualitydegradation.Ine con- omy, transportation plays an important role, which accounts for two-thirds of the total logistics cost and affects the level of customer service. In reality, food supply chains stretch fromupstreamagriculturalfarmstodownstreamconsu mers, withintermediatemanufacturers,foodserviceprovide rs,and sellers in the middle. Along the distribution process, food products may perish and temperature control becomes cru- cial for supply chain partners to reduce wastes and enhance foodqualityandfoodsafety.Toenhancetheprofitability and competitiveness, many enterprises strive to handle the issue of product perishability so as to maintain the value of their products.

The transportation planning problems are mainly con- cerned with the optimization of delivery routes, delivery quantities, and delivery time. Transportation modes, such as flights, cargo vessels, or trains, should also be considered. Although great progress has been made in this direction in terms of considering product perishability properties, challenges stillexist.

Transportationplanningmainlydealswithvehiclero ut- ing problems (VRP). When considering product perisha- bility,morefactorsshouldbereconsideredinthisrese arch area.First,foodsafetyisamainconcernwhenenterpri ses distributethefoodproductsfrommanufacturertoret ailers andcustomers.Forexample,Rijgersbergetal.[34]de vel- opedasimulationmodelofthedistributionchainoffr esh- cut iceberg lettuce under the consideration of quality and safetyduringdistributionstage.Second,differentty pesof perishableproductsshouldbestoredindifferentcond itions duringtransportation.Becausethestoragetemperat uresfor chilledmeatandfreshvegetablearedifferent,avehicl emay be divided up into multiple compartments with different temperature controls [35]. This makes the transportation planningmorecomplexandmorechallenging.Third ,dis- tribution planning of the food products is often linked to customers'preferencesandsatisfactions[36].Inreallif e,the fresherthe products,thehighertheprice.Shorterdeli very timehelpstomaintainthefreshness,yetitincreasesth etotal transportationcost.

Transportation Planning Considering Various Factors. Duringthetransportationofperishableproducts,factorslike the product quality, the product safety, the transportation mode, the preservation conditions, or multifirms' coordina- tionallhavesignificantimpactsonoptimaldecisions. Dabbeneetal.[37]assumedthatqualityoftheperishable products during transportation is directly linked to time and solved a distribution planning model by a heuristic approach. Quality change may lead to food safetyproblems. Rijgersberg et al. [34] also developed a simulation model of the distribution chain of fresh-cut iceberg lettuce under the considerationofqualityandsafetyduringdistributionstage. Themainpurposewastostudytheimpactsofproductlife cycle, customer purchasing behaviors, and distribution lead time reduction on distribution strategies.

Someresearchersdemonstratethattransportationmodes affect the optimal decisions significantly. Ahumada and Villalobos [38] considered transportation modes in their integrated production and distribution optimization models. They proposed that supply chain partners need to choose from the transportation modes of truck, rail, or air to distributetheirpackagedperishableproductsunderdifferent conditions. The impacts of refrigeration cost werediscussed in Dabbene et al. [39]. Rong andGrunow [40] studied the impacts of product dispersion during distribution on optimaldistributionplanningstrategies.Althoughdispersion enhances supply chain efficiency, it also causes food safety problems. Their approach allowed decision-makers to deal withthetradeoffunderdifferentriskattitudes.CaiandZhou [41]studied the optimal production and delivery policies when facing two markets (i.e., local market and foreign market) and the transportation to foreign market may be disrupted. An optimal policy was proposed to minimize the total cost. Eleonora and Jesus (2015) analyzed the schemes for food delivery to urban food sellers. They studied the impactsoftrafficregulations,deliveryservices,andanurban distribution center on the distribution efficiency in a case studyofParma,Italy.KetzenbergandFerguson[42]studied the value of information sharing between the seller and the supplier in a two-level supply chain. They showed in the numerical tests that information sharing not only improves profits of the two parties, but also benefits customers by enhancing productfreshness.

In addition to the impacts of quality, safety, and trans- portation modes, Grillo et al. [36] proposed a mixed integer mathematicalprogrammingmodeltostudyanorderpromis- ing process in fruit supply chains with subtypes of products considering various natural factors, such as land, weather, orharvestingtime.BilgenandGünther[43]studiedan integratedproblemforproductionanddistributionplanning. They considered two different transportation modes in the distribution stage between plants and distribution centers: the full truck load and less than truckload.

Soysaletal.[44]studiedaroutingproblemwithmultiple suppliers and customers considering food perishability and horizontalcollaborationbetweensupplychainpartners.They found that horizontal collaboration may reduce wastes and carbon emission and increase distribution efficiency of the whole supply chain. They used an experiment to study the impactsofrelatedfactorsandfoundthatthegainsarehighly sensitivetothesuppliersizeorthemaximumshelflifeof the products.

Transportation Combined with Inventory Problems. It is common that transportation planning is often related to inventory planning problems. The combined inventory- routing approaches not only solve the short term VRP problems,butalsohelptoovercomethelongtermproduction planningproblems.

Rong et al. [45] studied a joint production and distribu- tion planning model under the consideration of food quality degradation. In addition to routing and storage planning decisions, the firm also makes decisions on the temperature duringstorageanddistribution.Theproblemwassolvedwith agenericapproach.Farahanietal.[46]studiedanintegrated productionanddistributionplanningmodelforakindof fast perishable food product. To deal with the fast perishability, they proposed a policy to shorten the time interval between production and distribution. Adelman and Mersereau [47] studied a dynamic capacity allocation problem when cus- tomers' ordering quantity is correlated to fill rates in the past. In their model, customers risk attitudes to the fill rates were different. Given customers' differentiated behaviors, a dynamic rationing policy of the fill rates was proposed to achievehigherprofitandhighercustomersatisfaction. CoelhoandLaporte[48]studiedanintegratedreplen- ishment,distribution,andinventorymanagementproblemwhenproductshavevariouslifetimes.Theyshowedinthenumericalexperimentsthattheoptimalpolicyis eithertoselltheoldestavailableitemsfirsttoavoidspoilage,ortosell the fresher items first to increase revenue.Devapriyaetal.[49]studiedanintegratedproductionanddistributionschedulingproblemforperishableproductsinamultiechelonchain.Theirobjectivewastodeterminetheoptimalfleetsizeand trucks' routes in order to minimize theaggregatedcost.Unlike the previous research, their study capturedbothpro- duction and distribution planning undertheconsiderationoflimitedlifetimeoftheproducts.Amixedintegerpro- grammingmodelwasformulatedtosolvetheproblemandheuristicsbasedonevolutionaryalgorithmswereprovidedtoresolvethemodels.Liuetal.[50]studiedthedynamicinven- toryrationingproblemforperishableproductsovermultipleperiodsforawholesaler.Therationingstrategywasnotonlydetermined by the perishable properties of theproductsbutalso affected by the uncertain selling price inthefutureperiods.Qiuetal.[51]studiedageneralized production-inventory-routing problem for perishableproducts.Theyhavediscussedseveralinventorymanagementpoliciestoillustratethereal-worldapplicationsoftheproposedmodels.MoreworkscanbeseeninBilgenandGünther[43], Makkaretal.[52],Caietal.[53],RahdarandNookabadi[54], Uthayakumar and Priyan [55], Jiaet al. [56]Diabatetal. [57], Lee and Kim [58], Gaggero and Tonelli[59],Belo-Filhoetal.[60],PriyanandUthayakumar[61],SeyedhosseiniandGhoreyshi[62–64],Seletal.[65],MirzaeiandSeifi[66], Drezner and Scott [67], and Dobhan and Oberlaender [68].

Transportation Combined with Network Design Prob- lems. In food industry, there exist many kinds of distri- bution networks. In practice, the network design problem is to jointly optimize the location of hubs and the flows from upstream manufacturers to downstream retailers and customers. Distribution network design plays a key role in reducing transportation costs and maintaining quality of perishable products in food supply chains. However, many of the existing models on distribution network design only consider single period problems, which cannot be used to solve the problems for perishable products with time limitationswithinthenetworks.Tosolvethenetworkdesign problems, many new types of mathematical models and innovativealgorithmsweredevelopedinthelastdecade.

Firoozi et al. [69] studied a network design problem for perishable products which have limited storage time during transportation. Their model attempted to balance the benefit from enhancing storage conditions to maintain products quality and the associated costs to improve storage condi- tions.AnefficientLagrangianrelaxationheuristicalgorithm wasdevelopedtosolvetheproposedmodel.Firoozietal. [70] studied a similar network design problem considering product perishability. They proposed a memetic algorithm (MA) and proved that it works more efficiently than the Lagrangian relaxation heuristic algorithm. Unlike Firoozi et al. [69] and Firoozi et al. [70], Firoozi and Ariafar [71] con- sideredafluctuatedexpectedlifetimeofperishableproducts during transportation due to unusual weather condition or malfunction of transportation and storagefacilities.

Drezner and Scott [67] studied an inventory and loca- tion decisions in a network with a single distributor and multiplesalesoutletsforperishableproducts.Computational experiments showed that the location of the distribution centeraffectstheinventorydecisionssignificantly.Tsao[32] considered the joint location, inventory, and preservation decisions for a two-level supply chain with a supplier, a wholesaler, and multiple distribution centres. Algorithms were proposed to solve the nonlinear optimization models. Dulebenets et al. [72] studied an intermodal freight network designproblemwhichdealswiththedecisionsofproduction, inventory,andtransportation.Thenumericalcasesshowthat decaying cost significantly affects the transportation modes and the associated distribution routing. Rashidi et al. [73] formulated a biobjective mathematical model to optimize the joint location-inventory decisions in a network for perishable products. A Pareto-based metaheuristic approach was proposed to solve the models. de Keizer et al. [74] studiedthenetworkdesignproblemsforperishableproducts under different product quality and delivery lead time. The objective was to study the impacts of quality decay and its heterogeneity on optimal network design strategies. They usedamixedintegerprogrammingapproachtoformulatethe model, which is to maximize the total profit under quality constraints. The results showed that heterogeneous product quality decay has significant impacts on network designand profitability.

Summary. In this subsection, the papers on food products transportation problems are reviewed. In this area, people often study the transportation problems with various factors including product quality, product safety, transporta- tion mode, preservation conditions, and multifirms' coordi- nation. In addition, in real practice, transportation planning isoftencombinedwithinventoryplanningornetworkdesign or both. As such, we presented a comprehensive review of papers studying joint decisions of inventory-transportation problems and network design-transportationproblems.

Quality Based Pricing for Perishable Products. In this subsection, we summarize the up-to-date research on pric- ing problems related to time-linked quality for perishable products. Recently, customers are more concerned about foodsafetyandbecomemoresensitivetofoodqualitywhen purchasing food products. The demand for food products is highly linked to food quality. Due to the nature of food products, quality drops with time following a dynamicstate. Therefore,staticpricingstrategiesmayresultininappropriate quality control and excessive inventories in food supply chains. Many scholars did research on the dynamic pricing strategies to help firms reduce waste and enhance profit and foodsafety.

ModelswithSingleProductsandHomogenousCustomer Preferences.Intoday'sfoodsupplychains,varioustechnolo- gies (e.g., ratio frequency identification technology (RFID) andtimetemperatureindicator(TTI))canbeadoptedto cap- ture product information (e.g., temperature, humidity, and thetimeperiod)automatically.Thus,thiskindofinformation can be used to predict food quality and remaining shelf life, which supports the decisions on inventory control and pricing decisions. Besides, customers are often sensitive to the product quality and they alter their purchasing decisions toward products with differentqualities. FergusonandKoenigsberg[75]establishedatwo-period model, considering product quality decline, quality depen- dent demand, and competition. The research aims to opti- mally determine the prices and inventory to maximize the totalprofit.BlackburnandScudder[76]studiedsupply chain strategiestogetherwithpricingdecisionsbasedonperishable products' marginal-value-of-time (MVT). Sainathan [77] studiedthepricingandreplenishmentstrategiesforaperish- ableproductwithtwo-periodlifetimewhencustomers'utility is quality sensitive. In each period, new products and old productsweredifferentlypricedtomaximizethetotalprofit. WangandLi[78]proposedarealtimequalitybaseddynamic pricing model for perishable foods in a supply chain with quality sensitive customers. Compared to the static pricing strategy,thisquality-basedpricingstrategyhelpsreducefood spoilage waste and bring more profit to the retailers. A real case was also used to illustrate the results in the analytical models.

Adenso-D´ıazet al. [79] proved that dynamic pricing can significantlyreducethetotalwasteoftheperishableproducts, as Wang and Li [78] demonstrated. However, the spoilage reduction may come as a loss in total revenue that can vary dramatically, depending on the scenario and the speed of the price discount strategy. Also, based on the assumption that retailers can utilize time-temperature-indicator-based automatic devices, Herbon et al. [80] studied an optimal dynamic pricing model considering product perishability and customers' satisfactions. Herbon and Khmelnitsky [81] studied an integrated ordering and dynamic pricing model for perishable products when customers are highly sensitive to food quality. Unlike Wang and Li [78], they studied a continuousdynamicproblemratherthanadiscreteone. They also showed that the efficiency of the dynamic approach dependsontheformofdemandincorporatedintothemodel.

Models Considering Product Differentiation. Product differentiation is a factor that the retailers should consider whentheymakeorderingorpricingdecisions.Whenproduct lifetimeisconsidered,productsatdifferentagesaredifferent butstillsubstitutable,whichmayaffectcustomerpurchasing behaviors. Chew et al. [82] studied an integrated ordering and dynamic pricing problem for a kind of perishable product with multiperiod lifetime. The products at different ages, mutually substitutable, are all available in the market. The results showed that, under the assumption of product substitutions,theretailer'stotalprofitincreasessignificantly. Chen et al. [83] studied a combined pricing and inventory control problem considering product perishability with a fixed shelf life over a finite horizon. Heuristic policies were proposed to solve the models. In addition, they also proved that their model is applicable when the product's lifetime is stochastic.

Herbon[84]alsostudiedthepricingpoliciesforakindofperishableproductwithdifferentages.Theauthorcompared two strategies: fixed pricing and differentiated pricing. The author found that an optimal pricing policy is to implement pricediscriminationwithrespecttoconsumers'sensitivityto freshness, while dynamically changing the price over time, startingwithalowerpriceattheearlystagesoftheproduct's shelf life and increasing it at a later stage. Hu et al. [85] established a joint inventory and price markdown model considering customers' strategic behaviors. To reduce costs, the firm can either choose to discard the leftover inventory or set a clearance price. Li et al. [86] studied an inventory control problem with clearance sales strategies and product perishability. They proposed two myopic heuristics to solve the problems with partialinformation.

Models Considering Heterogeneous Customer Prefer- ences.Customersoftenhavedifferentvaluationstowardsthe same kind of products with same quality. Such customer heterogeneityonproductqualityforperishableproductshas alsobeenconsidered.Akçayetal.[87]studiedadynamic pricingproblemofafirmwhichsellsmultipledifferentiated productswithlinearrandomconsumerutilities.Gallegoand Hu [88] studied a dynamic price competition problem in an oligopolisticmarketwhenproductsperishovertime.Herbon [89]proposedapricingmodelunderconsumerheterogeneity inconsumers'sensitivitytofreshnessofaperishableproduct. He compared the model with and without the consideration of such heterogeneity. Also evaluated are the conditions in which a dynamic pricing policy is beneficial either to the retailerortotheconsumer,ascomparedwithastaticpricing policy.

In Herbon [90], customers were also assumed to be heterogeneous in their sensitivity to freshness, that is, their willingness to pay more for fresher products. A dynamic pricingmodelwasdevelopedtoevaluatetheextenttowhich boththeretailerandthecustomersbenefitfromthedynamic pricingpolicyasopposedtothestaticpricingpolicy.Herbon [91] also studied a model with multiple competing perish- ables with different remaining lifetimes and selling prices. It is found that when customers are homogeneous in their preferences, single-product-age operational mode outper- formsthemultiple-product- ageoperationalmode.Herbon [92] studied an inventory and pricing model considering customers'heterogeneitytowardstherealtimequality ofthe perishableproducts.Theeffectsofremainingshelf- life,price, and perceived quality on demand were investigated in their models.Also,itisshownthathighlyheterogeneitycanbenefit the sellers because more products will be sold. In addition, Herbon [93] demonstrated that customer information is crucial to determine firms' pricing decisions for perishable productsandcustomers'heterogeneouspreferencefor prod- uctfreshness.

Models Combined with Inventory Decisions. In many situations, inventory policies and pricing policies are mutu- allyaffectedinperishablefoodsupplychains.Pasternack [94]studied a pricing problem for a kind of perishable productcombinedwithcustomerreturns.Theauthorshowed that full credit provided by the manufacturer is effective in coordinating the supply chain when there is a single retailer. However it is not effective when facing multiple retailers. Li et al. [95] studied the pricing problem together with the inventory decisions in which price is linked to demandandproductshavetwo- periodlifetime.Lietal.[96] assume that product perishability affects demand. Based on this assumption, they studied the joint dynamic pricing and inventorycontrolproblemsforperishableproductswhenthe seller cannot sell new and old products at the same time. In each period, the seller determines to sell new products andmakesreplenishmentpoliciesortoselloldproducts and dispose of the inventory at the end of the period. The study shows counterintuitive result that profit maximization does not guarantee lowerexpirations.

ChenandSapra[97]studiedajointpricingand inventory decisionsforaperishableproductwithtwo- periodlifetimes. They compared the first-in-first-out with first-in-last-out strategies and found that bigger orders should be placed in the FIFO system. Chung and Erhun[98] studied a two-level supply chain coordination problem considering perishable products with two periods of shelf life. Kaya and Polat[99] studied a problem of jointly determining the optimal pricing and inventory replenishment strategy for a deterministic perishable inventory system in which demand is time and pricedependent.Thepriceadjustmentcost(alsocalled Menu cost) is considered when the seller changes its selling price during the lifetime of the products. Chen et al. [100] also considered Menu cost in their integrated dynamic inventory and pricing decisions models. They found that when Menu cost is moderate, a one-time price adjustment price policy outperforms the multitime price adjustment policy. Chua et al.[101]studiedtheoptimalpricediscountandreplenis hment policies for a perishable product with short lifetime and uncertaindemand.

Summary. In reality, customers are sensitive to the food qualities. Thus, to ensure the profit gains, firms need to provide more fresh products to customers. In the pre- sentedmodels,customers'preferenceisdirectlylinked tothe productqualityineachinstance.Inthefirstpart,research ers studied the single product pricing problems with homoge- nous customers' preference. Then models with multiple productsormultipletypesofcustomersarepresented.L astly, ordering decisions combined with pricing decisions are reviewed.

QuantitativeModelsofFoodTraceabilityandF oodRecall. In this subsection, we discuss the quantitative models using the information of traceability, which aims to improve prod- uctsafetyandhelpsfirmsreachfinancialtargets.Foodsa fety crisis can happen at any stage of food supply chains. Food traceability systems can record product attributes, such as quality and safety parameters, which can be used to capture information about ingredients, processing, storage, dates (sell-by,use- by),andsoon.Whenafoodsafetycrisisoccurs, the sold products should be recalled from the customer to mitigatethenegativeeffects.Governmentshaverealize dthe importance of food traceability and built food traceability system in many countries. For example, Hong et al. [102] discussed the financial model for applying RadioFrequency Identification(RFID)technologytoafoodtraceabilitys ystem in Taiwan. In addition, food crisis can bring great loss to enterprises. The application of traceability systems helps avoid such loss by reducing the impacts of food crisis. Required for regulatory and/or commercial purposes, they havebeenwidelyusedtoresolvetheissuesofproductrec all and food safety [103,104].
Thetraceabilitysystemsnotonlyimprovesocialwelfar es, but also contribute to firms' financial benefits. Dupuy etal.
[105] studied an optimization problem for food products under food quality risks and traceability systems. Under the given information, using a dispersion strategy, the firms can reduce the quantity of the recalled products, thus minimiz- ing their costs. Their research showed that the traceability systemshelpmitigatefoodriskstocustomers.Wangetal .
[106] studied an optimization problem considering food traceability in a multilevel supply chain to achieve desired product quality and minimizing the impact of product recall in an economic manner. They showed that utilizing traceability systems and traceability information contributes to the reduction of food quality risks. Wang et al. [107] also developed an integrated optimization model in which the traceability factors are incorporated with operations factors to determine the production batch size and batch dispersion. Resende-Filho and Hurley [108] studied the impacts of information asymmetry in a two-level supply chain with a supplier and a retailer implementing a traceability system. The retailer can offer payment to the supplier to induce its food safety effort. They found that traceability based batch dispersioncansubstitutefortheretailer'spayments.The yalso showed that mandatory implementation of the traceability systemmaynotleadtohigherfoodsafety,becauseitincr eases the firms'costs.
Piramuthu et al. [109] studied the recall problem in a three-level food network in which the products have contamination risks. They incorporated the long delay and the inaccuracy properties of the contamination source iden- tification in the optimization models. Comba et al. [110] proposed an optimization model to manage perishable bulk products under the use of traceability system. Although the implementation of food traceability systems helps reduce foodsafetyrisksinsociety,companiesmayhesitatetod oso if the recall cost or the traceability system implementation costistoohigh.Formostcompanies,theirfirstgoalistog ain financialbenefits.Assuch,managershavetobalanceth ecost incurred by food quality risks and that of recall of products or the implementation of the traceability systems. Memonet al. [111] proposed an integrated optimization model to minimize the expected loss to shareholders in recall crisis using batch dispersion methodology and taking into consid- eration recall costs. It is shown that higher traceability level decreasesthestakeholders'lossesduetorecallbutincre ases operational cost. Zhu [112] demonstrated that significant investment cost acts as a major obstacle for the diffusion of traceability systems in the food industry. They studied the economic outcomes for the implementation of a RFID- enabled traceability system in a two-level perishable food supply chain. Considering customers' perceptions of food quality and safety when using the traceability system, they proposed a dynamic pricing scheme, which helps reduce waste and improve the seller's performance. Dai et al. [113] also studied the pricing and tracking capacity

decisions considering different levels of food tracking cost and recall cost.Resultsshowthattherealwaysexistsauniquetracking capability and retailing/wholesale price with closed-form solutionstooptimizetheoverallsupplychainprofit.

In summary, the application of traceability system can help to optimize the recall strategies when food crisis hap- pens, therefore enhancing food safety. In the quantitative operations management models, when considering food traceability and food recall, inventory planning strategies [106,107],transportationplanningstrategies[109],andmar- ketingstrategies[112,113]willbechanged.However,thereis limitedresearchonthisareaandmoreworkscanbedone.

Directions for Future Research

In this section we give our suggestions for some future research topics. Although progress has been made in oper- ations management that accounts for food quality in recent years, there are still some challenges, which ought to be overcome in future research.

First of all, in the research area of inventory planning and transportation planning, more works should be done to formulate and solve stochastic optimization problems. It is widely agreed that demand can never be a deterministic parameter in this fast changing world. However, among the papers we reviewed, lots of them assume that demand is a constant parameter, or a price/quality dependent parameter. This assumption is quite unrealistic, which restricts the prac- ticabilityoftheproposedmodels.Althoughsomepapershave studied stochastic problems, no breakthrough occurs during the recent years. In this area, there are two directions for the researchers. One direction is to formulate new mathematical models to solve more realistic problems and solve them with existing methods. Another way is to find new methods to solve the stochastic models, which is more challenging and more important for the improvement of this researcharea.

Next, supply chain disruption should be consideredin theexistingmodels.Disruptioncanhappenatanystageof thefoodsupplychain.Itcanhappeneitherattheproduction stage,oratthetransportationstageduetovariousreasons includingweatherchanging,vehicledamaging,andmachine breakdown.Comparedtonormalproducts,disruptioncan even cause more severe damage in the food industry due to the short lifetime of the food products. Because, when the distributionisdelayed,qualityoftheproductswilldeteriorate in a short time. The prevalence of supply chain disruption in food supply chains makes it crucial to enterprises in the decision-making process. However, supply chain disruption isseldomincorporatedinthereviewedstudies.Inthefuture, one can reformulate the existing models by introducing supply chain disruptions into one of the distribution phases (inventory, transportation, and retailing) or into multiple phases.

In addition, food quality should be modeled in more practicalways.Intheexistingbodyofliterature,foodquality decayingisroughlymodeledandapproximatedwithin accu- rate parameters. The approximation does not guarantee the applicabilityofthemodelstoallproducts.Infutureresearch, more realistic factors need to be considered in modeling food quality in OM models, such as fast changing quality status, chemical and microbial properties of the food, and environmentalconditions.

Furthermore, the forward distribution and backward recallproblemsshouldbeintegrated.Inthepapersondistri- bution problems, some people studied the location problem. Also, in the recall problems, the location of the recall point also serves as a very important parameter. Therefore, when designinganetwork,enterprisesshouldconsidertheforward and backward flows simultaneously. In the future, one can formulate the models with both the distribution problems and the recall problems jointly, with a goal to enhance the firms' benefit and the foodsafety.

Last, it is also a future research direction to incorporate new product tracking or temperature control technologies. With these new technologies, additional information will be obtained and stored. This will lead to more advanced decision-making on food quality, more precise inventory control, and more efficient distributionsystems.

II. CONCLUSIONS

In this paper, we have reviewed the operations management research on food quality and safety. Unlike other disciplines that study food quality, the Operations Management (OM) field has focused on using optimization models to capture theeffectsofimportantoperationalvariables(e.g.,inventory, routing, and pricing) on both economic and social benefits. In some studies, food quality is modeled as a constraint to the storage or distribution time, while in others, it is modeled as a decreasing parameter which depends on the required preservation conditions or time. We classify the literature into four categories, ranging from inventory deci- sion for perishable food products, distribution problems for perishable food products, and dynamic pricing decisions for perishablefoodproductstooperationsmanagementfor food traceability and safety. Furthermore, we survey the research contributionsoftheliterature,discusstheup-to-dateresearch development, and identify challenges for further research within each category. The importance of product quality is reflected in the current research, in terms of both research contributions and the variety of the methodologiesused.

The future research agenda is also proposed to enrich the understanding of various kinds of operations management decisions and food quality.

REFERENCES

[1] M. M. Aungand Y. S. Chang, "Traceability in a food supply chain:safetyandqualityperspectives,"FoodControl,vol.39,no. 1, pp. 172–184,2014.

[2] FAO,Globalfoodlossesandfoodwaste–extent,causesandpre- vention, 2011,http://www.fao.org/docrep/014/mb060e/ mb060e.pdf.

[3] NRDC, Wasted: how America is losing up to 40 percent of its food from farm to fork to landfill, 2012, https://www.nrdc.org/ sites/default/files/wasted-food-IP.pdf.

[4] L.Young,"Ourbiggestproblem?Werewastingfood.Available from,"Accessedon,2012,http://www.canadiangrocer.com/top- stories/what-a-waste-19736.

[5] ReFED,Themulti-billiondollarfoodwasteproblem,2015,http://www.refed.com/?sort=economic-value-per-ton.

[6] FUSIONS,EstimatesofEuropeanfoodwastelevels,2016,http://www.eu-fusions.org/phocadownload/Publications/Estimates%20of%20European%20food%20waste%20levels.pdf.

[7] WHO'sfirsteverglobalestimatesoffoodbornediseasesfindchil-drenunder5accountforalmostonethirdofdeaths,WHOWorld Health Organization, 2015, http://www.who.int/mediacentre/ news/releases/2015/foodborne-diseaseestimates/en/.

[8] S. Mercier, S. Villeneuve, M. Mondor, and I. Uysal, "Time– Temperature Management Along the Food Cold Chain: A Review of Recent Developments," Comprehensive Reviews in FoodScienceandFoodSafety,vol.16,no.4,pp.647–667,2017.

[9] R.Badia-Melis, P.Mishra,andL.Ruiz-Garc´ıa,"Foodtraceabil-ity:Newtrendsandrecentadvances.Areview,"FoodControl, vol. 57, pp. 393–401,2015.

[10] R. Akkerman, P. Farahani, and M. Grunow, "Quality, safety andsustainabilityinfooddistribution:Areview ofquantitative operations management approaches and challenges," ORSpec-trum,vol.32,no.4,pp.863–904,2010.

[11] P.H.Hsu,H.M.Wee,andH.M.Teng,"Preservationtechnology investmentfordeterioratinginventory,"InternationalJournalof ProductionEconomics,vol.124,no.2,pp.388–394,2010.

[12] Y.-P. Lee and C.-Y. Dye, "An inventory model fordeteriorating items under stock-dependent demand and controllable deteri-orationrate,"Computers&IndustrialEngineering,vol.63,no.2, pp. 474–482,2012.

[13] C.-Y. Dye and T.-P. Hsieh, "An optimal replenishment policy fordeterioratingitemswitheffectiveinvestmentinpreservation technology,"EuropeanJournalofOperationalResearch,vol.218, no. 1, pp. 106–112,2012.

[14] C.-Y.Dye,"Theeffectofpreservationtechnologyinvestmenton anon-instantaneousdeterioratinginventorymodel," OMEGA-TheInternationalJournalofManagementScience,vol.41,no.5, pp. 872–880,2013.

[15] Y.-R. Chen and C.-Y. Dye, "Application of particle swarm optimisation for solving deteriorating inventory model with fluctuating demand and controllable deterioration rate," Inter-nationalJournalofSystemsScience,vol.44,no. 6,pp.1026–1039, 2013.

[16] Y. He and H. Huang, "Optimizing Inventory and Pricing Policy for Seasonal Deteriorating Products with Preservation TechnologyInvestment,"JournalofIndustrialEngineering,vol. 2013, pp. 1–7,2013.

[17] S. R. Singh and S. Sharma, "A global optimizing policy for decaying items with ramp-type demand rate under two-level trade credit financing taking account of preservation technol-ogy,"AdvancesinDecisionSciences,vol.2013,ArticleID126385, 2013.

[18] S. Bardhan, H. Pal, and B. C. Giri, "Optimal replenish- ment policy and preservation technology investment for a non-instantaneous deteriorating item with stock-

dependent demand,"OperationalResearch,pp.1–22,2017.

[19] C.-T. Yang, C.-Y. Dye, and J.-F. Ding, "Optimal dynamic trade credit and preservation technology allocation for a deteriorat- inginventorymodel,"Computers&IndustrialEngineering,vol. 87, article no. 4061, pp. 356–369,2015.

[20] C.-Y. Dye and C.-T. Yang, "Optimal dynamic pricing and preservation technology investment for deteriorating products withreferencepriceeffects,"Omega,vol.62,pp. 52–67,2016.

[21] C. Kouki, E. Sahin, Z. Jemaï, and Y. Dallery, "Assessing the impact of perishability and the use of time temperature tech- nologies on inventory management," International Journal of ProductionEconomics,vol.143,no.1,pp.72–85,2013.

[22] J. Zhang, Q. Wei, Q. Zhang, and W. Tang, "Pricing, service andpreservationtechnologyinvestmentspolicyfordeteriorat- ing items under common resource constraints," Computers & IndustrialEngineering,vol.95,pp.1–9,2016.

[23] U. Mishra, "An inventory model for controllable probabilistic deteriorationrateundershortages,"EvolvingSystems,vol.7,no. 4, pp. 287–307,2016.

[24] U.Mishra,S.Tiwari,A.A.Shaikh,andG.Treviño-Garza,"An inventory model under price and stock dependent demand for controllable deterioration rate with shortages and preservation technologyinvestment,"AnnalsofOperationsResearch,vol.254, no. 1-2, pp. 165–190,2017.

[25] Q.Li,P.Yu,andX.Wu,"ShelfLifeExtendingPackaging,Inven- tory Control and Grocery Retailing," Production Engineering ResearchandDevelopment,vol.26,no.7,pp.1369–1382,2017.

[26] S. Tayal, S. R. Singh, R. Sharma, and A. Chauhan, "Two ech- elon supply chain model for deteriorating items with effective investmentinpreservationtechnology,"InternationalJournalof MathematicsinOperationalResearch,vol.6,no.1,pp.84–105, 2014.

[27] J. Zhang, G. Liu, Q. Zhang, and Z. Bai, "Coordinating a supplychainfordeterioratingitemswitharevenuesharingand cooperative investment contract," OMEGA - The International JournalofManagementScience,vol.56,pp.37–49,2015.

[28] N. H. Shah, U. Chaudhari, and M. Y. Jani, "Optimal policies for time-varying deteriorating item with preservation technol- ogy under selling price and trade credit dependent quadratic demandinasupplychain,"InternationalJournal ofAppliedand ComputationalMathematics,vol.3,no.2,pp.363–379,2017.

[29] B. C. Giri, H. Pal, and T. Maiti, "A vendor-buyer supply chain modelfortime-dependentdeterioratingitemwithpreservation technologyinvestment,"InternationalJournalof Mathematicsin OperationalResearch,vol.10,no.4,pp.431–449,2017.

[30] X. Cai, J. Chen, Y. Xiao, and X. Xu, "Optimization and coor- dinationoffreshproductsupplychainswithfreshness-keeping effort," Production Engineering Research and Development, vol. 19, no. 3, pp. 261–278,2010.

[31] M. Yu and A. Nagurney, "Competitive food supply chain networkswithapplicationtofreshproduce,"EuropeanJournal ofOperationalResearch,vol.224,no.2,pp.273–282,2013.

[32] Y.-C. Tsao, "Joint location, inventory, and preservation deci- sions for non-instantaneous deterioration items under delay in payments,"InternationalJournalofSystemsScience,vol.47,no. 3, pp. 572–585,2016.

[33] Y.-C.Tsao,"Designingasupplychainnetworkfordeteriorating inventory under preservation effort and trade credits," Interna- tionalJournalofProductionResearch,vol.54,no.13,pp.3837– 3851,2016.

[34] H. Rijgersberg, S. Tromp, L. Jacxsens, and M. Uyttendaele, "Modeling logistic performance in quantitative microbial risk assessment,"RiskAnalysis,vol.30,no.1,pp.20–31,2010.

[35] U. Derigs, J. Gottlieb, J. Kalkoff, M. Piesche, F. Rothlauf,andU. Vogel, "Vehicle routing with compartments: Applications, modellingandheuristics,"ORSpectrum,vol.33,no.4,pp.885– 914,2011.

[36] H.Grillo,M.M.E.Alemany,A.Ortiz,andV.S.Fuertes-Miquel, "Mathematical modelling of the order-promising process for fruit supply chains considering the perishability and subtypes ofproducts,"AppliedMathematicalModelling,vol.49,pp.255– 278,2017.

[37] F. Dabbene, P. Gay, and N. Sacco,

"Optimisation of fresh-food supply chains in uncertain environments, Part I: Background and methodology," Biosystems Engineering, vol. 99, no. 3, pp. 348–359,2008.

[38] O.AhumadaandJ.R.Villalobos,"Atacticalmodelforplanning the production and distribution of fresh produce," Annals of OperationsResearch,vol.190,pp.339–358,2011.

[39] F. Dabbene, P. Gay, and N. Sacco, "Optimisation of fresh-food supplychainsinuncertainenvironments,PartII: Acasestudy," BiosystemsEngineering,vol.99,no.3,pp.360–371,2008.

[40] A. Rong and M. Grunow, "A methodology for controlling dispersion in food production and distribution," OR Spectrum, vol. 32, no. 4,pp. 957–978, 2010.

[41] X. Cai and X. Zhou, "Optimal policies for perishable products when transportation to export market is disrupted," Production EngineeringResearchandDevelopment,vol.23,no.5,pp.907– 923,2014.

[42] M. Ketzenberg and M. E. Ferguson, "Managing slow-moving perishables in the grocery industry," Production Engineering ResearchandDevelopment,vol.17,no.5,pp.513–521,2008.

[43] B.BilgenandH.-O.Günther,"Integratedproductionanddistri- bution planning in the fast moving consumer goods industry: Ablockplanningapplication,"ORSpectrum,vol.32,no.4,pp. 927–955,2010.

[44] M.Soysal,J.M.Bloemhof-Ruwaard,R.Haijema,andJ.G.A.J. vanderVorst,"Modelingagreeninventoryroutingproblemfor perishable products with horizontal collaboration," Computers & Operations Research,2016.

[45] A. Rong, R. Akkerman, and M. Grunow, "An optimization approach for managing fresh food quality throughout the supply chain," International Journal of Production Economics, vol.131,no.1,pp.421–429,2011.

[46] P.Farahani,M.Grunow,andH.-O.Günther,"Integratedpro- duction and distribution planning for perishable food prod- ucts,"FlexibleServicesandManufacturingJournal,vol.24,no. 1, pp. 28–51,2012.

[47] D.AdelmanandA.J.Mersereau,"Dynamiccapacityallocation tocustomerswhorememberpastservice,"ManagementScience, vol.59,no.3,pp.592–612,2013.

[48] L. C. Coelho and G. Laporte, "Optimal joint replenishment, delivery and inventory management policies for perishable products,"Computers&OperationsResearch,vol.47,pp.42–52, 2014.

[49] P. Devapriya, W. Ferrell, and N. Geismar, "Integrated produc- tion and distribution scheduling with a perishable product," EuropeanJournalofOperationalResearch,vol. 259,no.3,pp. 906–916, 2017.

[50] H. Liu, J. Zhang, C. Zhou, and Y. Ru, "Optimal purchase and inventoryretrievalpoliciesforperishableseasonalagricultural products," OMEGA - The International Journal ofManagement Science,2017.

[51] Y. Qiu, J. Qiao, and P. M. Pardalos, "Optimal production, replenishment, delivery, routing and inventory management policiesforproductswithperishableinventory," Omega,2018.

[52] S. Makkar, P. C. Jha, and N. Arora, "Single-source, single-destinationcoordinationofEOQmodelforperishableproducts with quantity discounts incorporating partial/full truckload policy under fuzzy environment," Advances in Intelligent and SoftComputing,vol.130,no.1,pp.971–982,2012.

[53] X.Cai,J.Chen,Y.Xiao,X.Xu,andG.Yu,"Fresh-productsupply chain management with logistics outsourcing," OMEGA - The InternationalJournalofManagementScience,vol.41,no.4,pp. 752–765,2013.

[54] M.RahdarandA.S.Nookabadi,"Coordination mechanismsfor adeterioratingiteminatwo-levelsupplychainsystem,"Applied Mathematical Modelling, vol. 38, no. 11-12, pp. 2884–2900,2014.

[55] R. Uthayakumar and S. Priyan, "Pharmaceutical supply chain andinventorymanagementstrategies:optimizationforaphar- maceuticalcompany and a hospital," Operations Research for HealthCare,vol.2,no.3,pp.52–64,2013.

[56] T.Jia,X.Li,N.Wang,andR.Li,"Integratedinventoryrouting problem with quality time windows and loading cost for dete- rioratingitemsunderdiscretetime,"MathematicalProblemsin Engineering,vol.2014,ArticleID537409,2014.

[57] A. Diabat, T. Abdallah, and T. Le, "A hybrid tabu search based heuristic for the periodic distribution inventory problem with perishablegoods,"AnnalsofOperationsResearch,vol.242,no. 2, pp. 373–398,2016.

[58] S. Lee and D. Kim, "An optimal policy for a

single-vendor single-buyer integrated production-distribution model with bothdeterioratinganddefectiveitems,"InternationalJournalof ProductionEconomics,vol.147,pp.161–170,2014.

[59] M. Gaggero and F. Tonelli, "Optimal control of distribution chainsforperishablegoods,"IFAC-PapersOnLine,vol.28,no. 3, pp. 1049–1054,2015.

[60] M.A.F.Belo-Filho,P.Amorim,andB.Almada-Lobo,"Anadap- tive large neighbourhood search for the operational integrated production and distribution problem of perishable products," InternationalJournalofProductionResearch,vol.53,no.20,pp. 6040–6058,2015.

[61] S. Priyan and R. Uthayakumar, "An integrated production-distributioninventorysystemfordeterioratingproductsinvolv- ing fuzzy deterioration and variable setup cost," Journal of Industrial and Production Engineering, vol. 31, no. 8,pp. 491– 503,2014.

[62] S.M.SeyedhosseiniandS.M.Ghoreyshi,"Anintegratedmodel for production and distribution planning of perishable prod- ucts with inventory and routing considerations," Mathematical ProblemsinEngineering,vol.2014,ArticleID475606,2014.

[63] S. M. Seyedhosseini and S. M. Ghoreyshi, "Integration of production and distribution decisions of perishable products considering feasible delivery routes," International Journal of AppliedManagementScience,vol.6,no.3,pp.267–284,2014.

[64] S. M. Seyedhosseini and S. M. Ghoreyshi, "An integrated production and distribution planning model for perishable products," International Journal of Operational Research, vol. 23, no. 3, pp. 268–283,2015.

[65] C.Sel,B.Bilgen,J.M.Bloemhof-Ruwaard,andJ.G.A.J.vander Vorst, "Multi-bucket optimization for integrated planning and schedulingintheperishabledairysupplychain," Computers& ChemicalEngineering,vol.77,pp.59–73,2015.

[66] S. Mirzaei and A. Seifi, "Considering lost sale in inventory routingproblemsforperishablegoods,"Computers&Industrial Engineering, vol.87, pp. 213–227, 2015.

[67] Z. Drezner and C. H. Scott, "Location of a distribution center foraperishableproduct,"MathematicalMethodsofOperations Research,vol.78,no.3,pp.301–314,2013.

[68] A. Dobhan and M. Oberlaender, "Hybrid contracting within multi-location networks," International Journal of Production Economics,vol.143,no.2,pp.612–619,2013.

[69] Z.Firoozi,N.Ismail,S.Ariafar,S.H.Tang,M.K. A.M.Ariffin, and A. Memariani, "Distribution network design for fixed lifetime perishable products: A model and solution approach," JournalofAppliedMathematics,vol.2013,ArticleID891409, 2013.

[70] Z.Firoozi,N.Ismail,andS.Ariafar,"Effectsofintegrationon thecostreductionindistributionnetworkdesign forperishable products," Mathematical Problems in Engineering, vol. 2014, ArticleID739741,10pages,2014.

[71] Z. Firoozi and S. Ariafar, "A supply chain network design modelforrandom-lifetimeproducts,"JournalofIndustrialand ProductionEngineering,vol.34,no.2,pp.113–123,2017.

[72] M. A. Dulebenets, E. E. Ozguven, R. Moses, and M. B. Ulak, "Intermodal Freight Network Design for Transport of PerishableProducts,"OpenJournalofOptimization,vol.05,no. 04, pp. 120–139,2016.

[73] S. Rashidi, A. Saghaei, S. J. Sadjadi, and S. Sadi-Nezhad, "Optimizing supply chain network design with location- inventory decisions for perishable items: A Pareto-based MOEAapproach,"ScientiaIranica,vol.23,no.6, pp.3035–3045, 2016.

[74] M. de Keizer, R. Akkerman, M. Grunow, J. M. Bloemhof, R. Haijema, and J. G. van der Vorst, "Logistics networkdesignfor perishable products with heterogeneous quality decay," EuropeanJournalofOperationalResearch,vol. 262,no.2,pp. 535–549, 2017.

[75] M.E.FergusonandO.Koenigsberg,"Howshouldafirmman-agedeterioratinginventory?"ProductionEngineeringResearch andDevelopment,vol.16,no.3,pp.306–321,2007.

[76] J. Blackburn and G. Scudder, "Supply chain strategies for perishable products: the case of fresh produce," Production EngineeringResearchandDevelopment,vol.18,no.2,pp.129– 137, 2009.

[77] A. Sainathan, "Pricing and replenishment of competing per- ishable product variants under dynamic demand substitution,"

ProductionEngineeringResearchandDevelopment,vol.22,no. 5, pp. 1157–1181,2013.

[78] X.WangandD.Li,"Adynamicproductqualityevaluationbased pricingmodelforperishablefoodsupplychains,"Omega,vol. 40, no. 6, pp. 906–917,2012.

[79] B.Adenso-D´ıaz,S.Lozano,andA.Palacio,"Effectsofdynamic pricing of perishable products on revenue and waste," Applied MathematicalModelling,vol.45,pp.148–164,2016.

[80] A.Herbon,E.Levner,andT.C.E.Cheng,"Perishableinventory management with dynamic pricing using time-temperature indicators linked to automatic detecting devices," International JournalofProductionEconomics,vol.147,pp.605–613,2014.

[81] A. Herbon and E. Khmelnitsky, "Optimal dynamic pricing and ordering of a perishable product under additive effects of price and time on demand," European Journal of Operational Research,vol.260,no.2,pp.546–556,2017.

[82] E.P.Chew,C.Lee,R.Liu,K.-S.Hong,andA.Zhang,"Optimal dynamic pricing and ordering decisions for perishable prod-ucts,"InternationalJournalofProductionEconomics,vol.157,no. 1, pp. 39–48,2014.

[83] X.Chen,Z.Pang,andL.Pan,"Coordinatinginventorycontrol and pricing strategies for perishable products," Operations Research,vol.62,no.2,pp.284–300,2014.

[84] A. Herbon, "Optimal two-level piecewise-constant price dis- crimination for a storable perishable product," International Journal of Production Research,2015.

[85] P. Hu, S. Shum, and M. Yu, "Joint inventory and markdown management for perishable goods with strategic consumer behavior,"OperationsResearch,vol.64,no.1,pp.118–134,2016.

[86] Q. Li, P. Yu, and X. Wu, "Managing perishable inventories in retailing: replenishment, clearance sales, and segregation," OperationsResearch,vol.64,no.6,pp.1270–1284,2016.

[87] Y.Akçay,H.P.Natarajan,andS.H.Xu,"Jointdynamicpricing of multiple perishable products under consumer choice," Man-agementScience,vol.56,no.8,pp.1345–1361,2010.

[88] G. Gallego and M. Hu, "Dynamic pricing of perishable assets under competition," Management Science, vol. 60, no. 5, pp. 1241–1259,2014.

[89] A. Herbon, "Dynamic pricing vs. acquiring information on consumers heterogeneous sensitivity to product freshness," InternationalJournalofProductionResearch,vol.52,no.3,pp. 918–933,2014.

[90] A.Herbon,"Optimalpiecewise-constantpriceunderheteroge-neoussensitivitytoproductfreshness,"InternationalJournalof ProductionResearch,vol.54,no.2,pp.365–385,2016.

[91] A. Herbon, "Should retailers hold a perishable product having different ages? The case of a homogeneous market and mul-tiplicativedemandmodel,"InternationalJournalofProduction Economics,vol.193,pp.479–490,2017.

[92] A.Herbon,"OptimalPricingandReplenishmentofanExpiring Inventoried Product under Heterogeneous Consumer Sensitiv- ities," Decision Sciences,2017.

[93] A. Herbon, "Potential additional profits of selling a perish- able product due to implementing price discrimination versus implementation costs," International Transactions in Opera- tional Research,2017.

[94] B. A. Pasternack, "Optimal pricing and return policies for perishable commodities," Marketing Science, vol. 27, no. 1, pp. 133–140,2008.

[95] Y.Li,A.Lim,andB.Rodrigues,"Pricingandinventorycontrol foraperishableproduct,"ManufacturingandServiceOperations Management,vol.11,no.3,pp.538–542,2009.

[96] Y. Li, B. Cheang, and A. Lim, "Grocery perishables manage-ment,"ProductionEngineeringResearchandDevelopment,vol. 21, no. 3, pp. 504–517,2012.

[97] L.-M. Chen and A. Sapra, "Joint inventory and pricing deci- sions for perishable products with two-period lifetime," Naval ResearchLogistics(NRL),vol.60,no.5,pp.343–366,2013.

[98] Y. T. Chung and F. Erhun, "Designing supply contracts for perishable goods with two periods of shelf life," Institute of IndustrialEngineers(IIE).IIETransactions,vol.45,no.1,pp.53– 67,2013.

[99] O. Kaya and A. L. Polat, "Coordinated pricing and inventory decisionsforperishableproducts,"ORSpectrum,vol.39,no.2, pp. 589–606,2017.

[100] J. Chen, M. Dong, Y. Rong, and L. Yang, "Dynamic pricing for deteriorating products with menu cost," OMEGA - The InternationalJournalofManagementScience,2

015.

[101] G. A. Chua, R. Mokhlesi, and A. Sainathan, "Optimal Dis- counting and Replenishment Policies for Perishable Products," InternationalJournalofProductionEconomics, vol.186,pp.8– 20, 2017.

[102] I.-H. Hong, J.-F. Dang, Y.-H. Tsai et al., "An RFID application inthefoodsupplychain:Acasestudyofconvenie ncestoresin Taiwan,"JournalofFoodEngineering,vol.106,no. 2,pp.119–126, 2011.

[103] K.M.Karlsen,B.Dreyer,P.Olsen,andE.O.Elve voll,"Literature review: Does a common theoretical framework to implement food traceability exist?" Food Control, vol. 32, no. 2, pp.409– 417, 2013.

[104] T.BosonaandG.Gebresenbet,"Foodtraceabilit yasanintegral part of logistics management in food and agricultural supply chain,"FoodControl,vol.33,no.1,pp.32– 48,2013.

[105] C.Dupuy,V.Botta- Genoulaz,andA.Guinet,"Batchdispersion modeltooptimisetraceabilityinfoodindustry,"J ournalofFood Engineering,vol.70,no.3,pp.333–339,2005.

[106] X. Wang, D. Li, and C. O'Brien, "Optimisation of traceability and operations planning: an integrated model for perishable foodproduction,"InternationalJournalofProdu ctionResearch, vol. 47, no. 11, pp. 2865–2886,2009.

[107] X. Wang, D. Li, C. O'brien, and Y. Li, "A production planning model to reduce risk and improve operations management," InternationalJournalofProductionEconomics, vol.124,no.2, pp. 463–474,2010.

[108] M. A. Resende-Filho and T. M. Hurley, "Information asym- metry and traceability incentives for food safety," International JournalofProductionEconomics,vol.139,no.2, pp.596–603, 2012.

[109] S. Piramuthu, P. Farahani, and M. Grunow, "RFID-generated traceability for contaminated product recall in perishablefood supply networks," European Journal of Operational Research, vol. 225, no. 2, pp. 253–262, 2013.

[110] L. Comba, G. Belforte, F. Dabbene, and P. Gay, "Methods for traceability in food production processes involving bulk products,"BiosystemsEngineering,vol.116,no.1, pp.51–63,2013.

[111] M.S.Memon,Y.H.Lee,andS.I.Mari,"Analysis ofTraceability Optimization and Shareholder's Profit for Efficient Supply Chain Operation under Product Recall Crisis," Mathematical ProblemsinEngineering,vol.2015,ArticleID8 96239,2015.

[112] L. Zhu, "Economic analysis of a traceability system for a two- levelperishablefoodsupplychain,"Sustainabilit y,vol.9,no.5, article no. 682,2017.

[113] J. B.Dai,L.Fan,N.K.S.Lee,andJ.Li, "Jointoptimisationof trackingcapabilityandpriceinasupplychainwit hendogenous pricing,"InternationalJournalofProductionRes earch,vol.55, no. a18, pp.