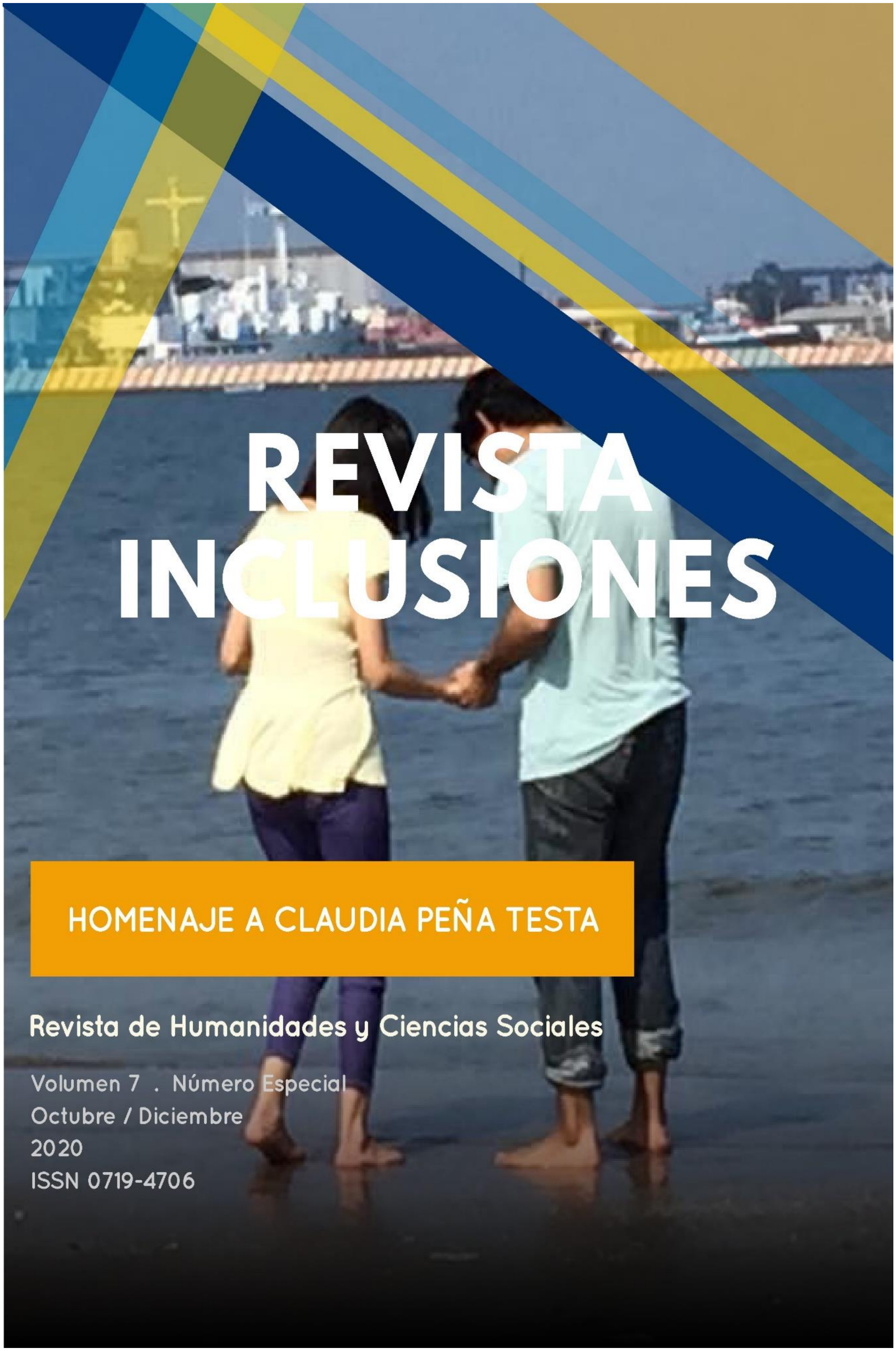


REVISTA INCLUSIONES

HOMENAJE A CLAUDIA PEÑA TESTA

Revista de Humanidades y Ciencias Sociales

Volumen 7 . Número Especial
Octubre / Diciembre
2020
ISSN 0719-4706

REVISTA INCLUSIONES M.R.
REVISTA DE HUMANIDADES
Y CIENCIAS SOCIALES

CUADERNOS DE SOFÍA
EDITORIAL

REVISTA INCLUSIONES M.R.
REVISTA DE HUMANIDADES Y CIENCIAS SOCIALES

CUADERNOS DE SOFÍA EDITORIAL

Editorial Cuadernos de Sofía
Santiago – Chile
OBU – C HILE

Indización, Repositorios y Bases de Datos Académicas

Revista Inclusiones, se encuentra indizada en:

CATÁLOGO

BIBLIOTECA UNIVERSIDAD DE CONCEPCIÓN

REVISTA INCLUSIONES M.R.
REVISTA DE HUMANIDADES Y CIENCIAS SOCIALES

CUADERNOS DE SOFÍA EDITORIAL

ISSN 0719-4706 - Volumen 7 / Número Especial / Octubre – Diciembre 2020 pp. 387-398

SIMULATION MODELLING METHODS FOR IDENTIFICATION AND FORECASTING OF KEFIR PRODUCTION

Ph. D. (c) Evgeny Anatolevich Nazoykin
Moscow State University of Food Production, Russia
ORCID: 0000-0002-7859-1117
mirovind@yandex.ru
Ph. D. (c) Ivan Germanovich Blagoveshchensky
Moscow State University of Food Production, Russia
ORCID: 0000-0002-7862-680X
igblagov@gmail.com

Fecha de Recepción: 04 de junio de 2020 – **Fecha Revisión**: 19 de junio de 2020

Fecha de Aceptación: 27 de septiembre 2020 – **Fecha de Publicación**: 01 de octubre de 2020

Abstract

This article is devoted to urgent issues of optimization of production processes as exemplified by kefir production. In order to solve the highlighted issues, it is proposed to develop control subsystem on the basis of multi-agent simulation modelling. Aiming at development and implementation of the model, this article thoroughly analyzes kefir production at dairy factories. On the basis of analyzed regularities, recommendations are given for implementation of multi-agent simulation model of kefir production used for analysis of optimization and detection of bottlenecks of the production process using simulation experiment. AnyLogic simulation modelling tool was used for the analysis and implementation of the model. On the basis of experiments with simulation model, the quantitative indicators of production output are estimated and recommendations are given to plan and to control kefir production at similar factories.

Keywords

Food enterprises – Models – Management – Forecasting – Optimization – Identification

Para Citar este Artículo:

Nazoykin, Evgeny Anatolevich y Blagoveshchensky, Ivan Germanovich. Simulation modelling methods for identification and forecasting of kefir production. Revista Inclusiones Vol: 7 num Especial (2020): 387-398.

Introduction

Dairy industry is one of the rapidly developing and dynamic industries in Russia. According to the data of Ministry of Agriculture of Russia for 2019, production of milk reached 31.1 mln t. Numerous adjacent industries are interrelated with milk production and their success directly depends on steady operation of dairy industry. One workplace in dairy industry results in up to eight workplaces in adjacent industries.

Kefir is one of the main milk products. Kefir production is based on numerous physicochemical, biochemical, biological and other processes determining quality and taste properties of finished products, the management of these processes aiming at production of drink of the best quality requires for understanding of equipment and technology, innovation methods of operation, increased concentration and responsibility upon fulfillment of the formulated tasks.

Application of simulation modelling makes it possible to detect and to analyze the behavior of industrial enterprise (milk factory) in the course of virtual time. One of the key factors is the possibility of time control: deceleration of time upon consideration of rapid processes and acceleration upon analysis of unsteady systems. Multi-agent simulation makes it possible to create several copies of selected equipment with preset properties for observation of the objects (agents), for which actual experiments are dangerous, expensive, or impossible. Execution of complicated and unique production processes is closely related with development of simulation model. Applying this approach, it becomes possible to perform comprehensive analysis of a factory.

Therefore, enterprises of dairy industry require for flexible tool of identification and forecasting, and such tool is multi-agent simulation modelling, since it allows to carry out:

- various modifications in enterprise structure in order to obtain high profitability;
- estimation of equipment operation and its performances, thus providing detection of bottlenecks of production line;
- simulation and forecasting of production modernization without significant expenses.

Literature Review

Nowadays high attention is paid to digitalization of production processes and creation of virtual twins to perform computer experiments[1]. In particular, classical implementation of simulation modelling is considered[2]; however, such approach does not take into account

[1] A. A. Sirota, Komp'yuternoe modelirovanie i otsenka effektivnosti slozhnykh sistem: Guidebook (Moscow: Tekhnosfera, 2006); B. Ya. Sovetov y S. A. Yakovlev, Modelirovanie sistem: Guidebook (Moscow: Vysshaya shkola, 2007) y A. Fajar y R. Sarno, “Asynchronous agent-based simulation and optimization of parallel businesss”, Telkomnika (Telecommunication Computing Electronics and Control) Vol: 17 num 4 (2019): 1731-1739.

[2] K. E. Gabrin y E. A. Kozlova, Osnovy imitatsionnogo modelirovaniya v ekonomike i upravlenii: Guidebook (Chelyabinsk: YuUrGU, 2004); Yu. G Karpov, Imitatsionnoe modelirovanie sistem: vvedenie v modelirovanie s pomoshch'yu AnyLogic 5 (+ CD) (St. Petersburg: BKhV-Peterburg, 2005);

actual dynamics of variation of observed variables of production process. During implementation of complicated production systems[3], the most actual is application of multi-agent simulation modelling[4]; such method describes in more details all stages and properties of production process[5] and allows to identify exactly the considered variables.

Methods

Substantiation

Kefir is a fermented milk drink, which is a product of mixed lactic acid and alcoholic fermentation, it is produced by ripening of milk with buttermilk fungus, symbiotic buttermilk or starters.

The main production is comprised of three sites[6]:

– hardware–raw materials shop;

– filling and packing site;

– site of laying and storage of products.

The hardware–raw materials shop is presented by the following sites:

– acceptance of raw milk;

– production and storage of pasteurized milk;

– mixing/recombination of milk;

– production of sterilized milk and fermented products.

An enterprise of milk production can be presented in the form of multiphase multichannel open queue system with waiting; let us present the enterprise in the form of queue system as illustrated in Fig. 1.

V. D. Boev; D. I. Kirik y R. P. Sypchenko, Komp'yuternoe modelirovanie: Guidebook (St. Petersburg: VAS, 2011) y V. D. Boev; D. I. Kirik y R. P. Sypchenko, Komp'yuternoe modelirovanie…

[3] Yu. A. Ivashkin y E. A. Nazoikin, “Mul'tiagentnoe modelirovanie protsessa nakopleniya znanii”, Programmnye produkty i sistemy num 1 (2011): 47-52.

[4] E. A. Nazoikin; I. G. Blagoveshchenskii; M. M. Blagoveshchenskaya y R. R. Naumov, “Identifikatsiya protsessov proizvodstva marmeladnykh mass s ispol'zovaniem metodov imitatsionnogo modelirovaniya”, Pishchevaya industriya Vol: 1 num 39 (2019): 40-41.

[5] E. A. Nazoikin; I. G. Blagoveshchenskii; M. M. Blagoveshchenskaya y R. R. Naumov, Primenenie agentnykh tekhnologii v analize proizvodstvennykh protsessov pishchevykh proizvodstv, In: Advanced food technologies: status, trends, points of increase: proceedings. November 29-30, 2018.

[6] M. M. Blagoveshchenskaya y L. A. Zlobin, Informatsionnye tekhnologii sistem upravleniya tekhnologicheskimi protsessami (Moscow: Vysshaya shkola, 2010).

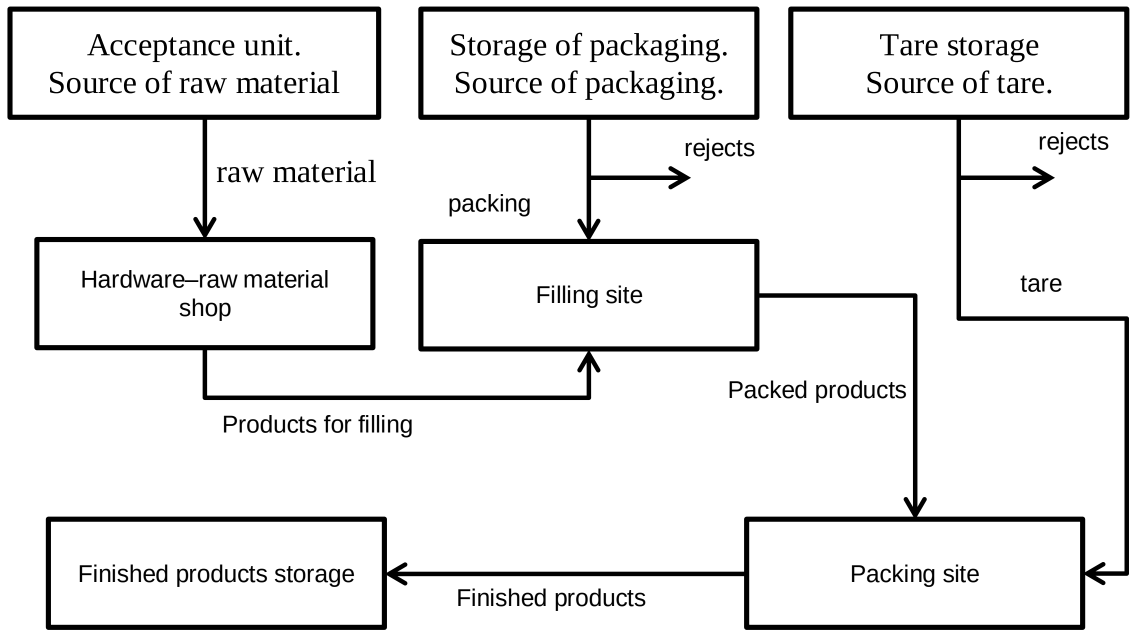


Figure 1
Dairy factory as queue system

On the basis of general structure of production process, it is possible to develop flowchart of production processes, that is, to develop conceptual model using UML diagram of equipment classes[7].

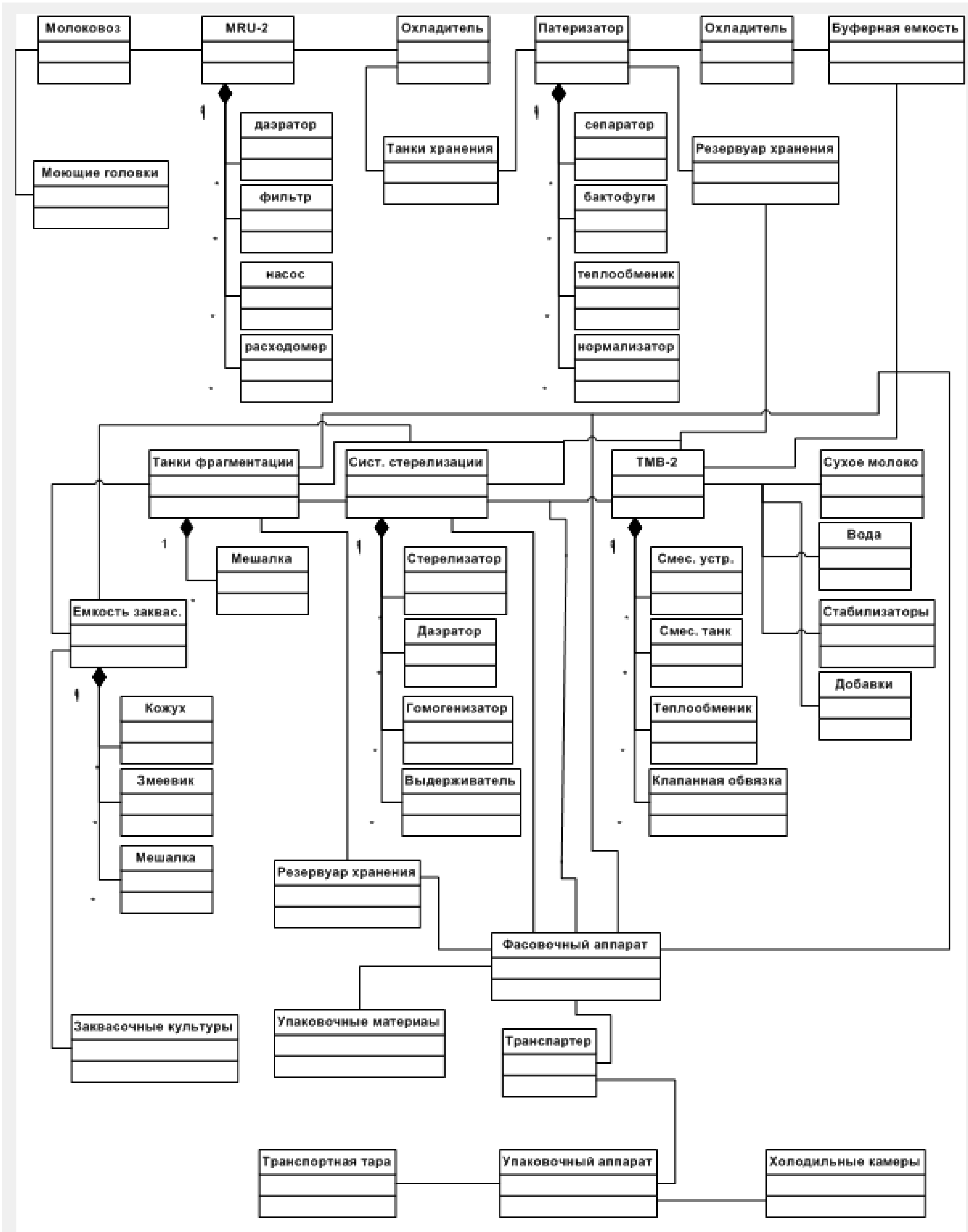
The diagram of classes is required for visualization of static system model in terms of classes of object-oriented programming.

In particular, the diagram of classes reflects various interrelations between single essences of the considered field, in our case between the production segments, hence, promotes the description of their internal structure and types of interrelations.

During the studies, the following diagram of equipment classes was implemented, illustrated in Fig. 2.

While describing the functional flowchart of the considered production process and implementing the diagram of classes, it is possible to implement it in AnyLogic simulation modelling environment on the basis of multi-agent approach.

[7] A. V. Leonenko, Samouchitel' UML (St. Petersburg: BKhV-Petersuburg, 2004).


Молоковоз
MRU-2
Охладитель
Патеризатор
Охладитель
Буферная емкость
Моющие головки
даэратор
фильтр
насос
расходомер
Танки хранения
сепаратор
бактофуги
теплообменик
нормализатор
Резервуар хранения
Танки фрагментации
Сист. стерелизации
ТМВ-2
Сухое молоко
Вода
Стабилизаторы
Добавки
Мешалка
Емкость заквас.
Стерелизатор
Даэратор
Гомогенизатор
Выдерживатель
Смес. устр.
Смес. танк
Теплообменик
Клапанная обвязка
Кожух
Змеевик
Мешалка
Резервуар хранения
Фасовочный аппарат
Заквасочные культуры
Упаковочные материаы
Транспартер
Транспортная тара
Упаковочный аппарат
Холодильные камеры

Молоковоз	Milk tanker
Охладитель	Cooler
Пастеризатор	Pasteurizer
Охладитель	Cooler
Буферная емкость	Surge tank
Моющие головки	Washing heads
Деаэратор	Deaerator
фильтр	Filter
насос	Pump
расходомер	Flow meter
Танки хранения	Storage tanks
сепаратор	Separator
бактофуги	Bactofuges
теплообменник	Heat exchangers
нормализатор	Normalizer
Резервуар хранения	Storage tank
Танки фрагментации	Fermentation tanks
мешалка	Mixer
Емкость заквас.	Starter tank
Кожух	Shell
Змеевик	Coil
Мешалка	Mixer
Сист. стерилизации	Sterilization system
Стерилизатор	Sterilizer
Деаэратор	Deaerator
Гомогенизатор	Homogenizer
Выдерживатель	Holding tank
Смес. устр.	Mixing device
Смес. танк	Mixing tank
Теплообменник	Heat exchanger
Клапанная обвязка	Valve assembly
Сухое молоко	Powdered milk
Вода	Water
Стабилизаторы	Stabilizers
Добавки	Additives
Резервуар хранения	Storage tank
Фасовочный аппарат	Packing device
Заквасочные культуры	Starter cultures
Упаковочные материалы	Packing materials
Фасовочный аппарат	Packing device
Транспортер	Transporter
Транспортная тара	Transporting tare
Упаковочный аппарат	Packing device
Холодильные камеры	Refrigerating chambers

Figure 2
Equipment class diagram

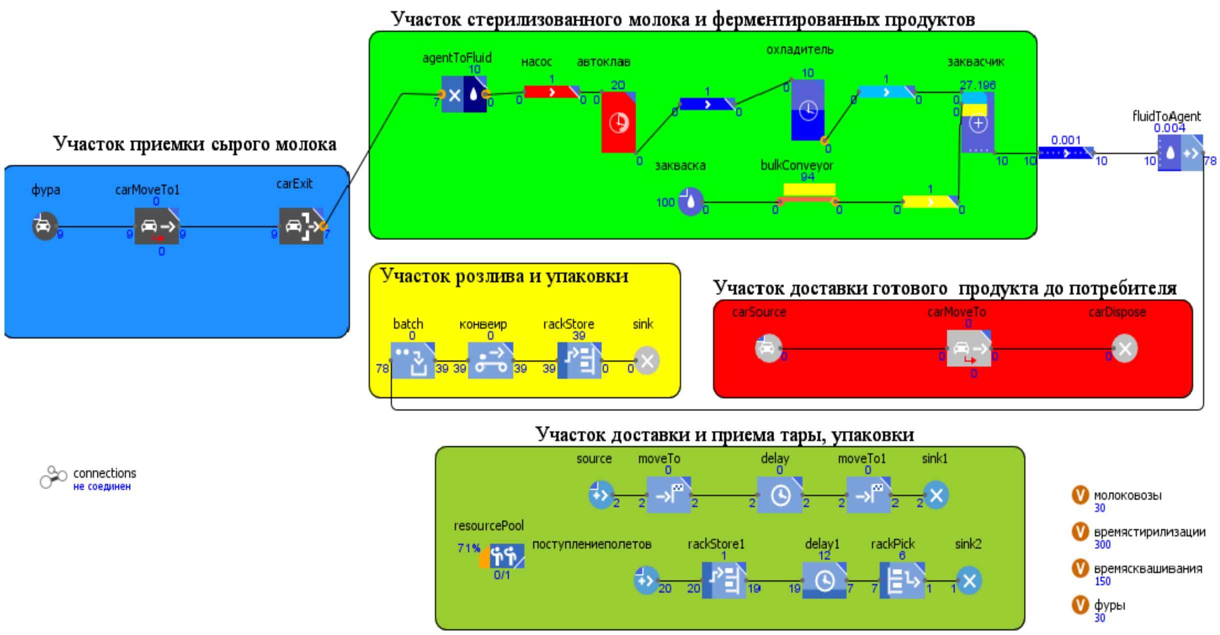
Stages

On the basis of the analysis at the level of conceptual model as well as upon development of UML diagram of equipment classes, the main model variables were determined required for its correct operation (Table 1).

riable	ta type	scription
Factory variables		
Ob'emAvto	int	Amount of raw material delivered by each tanker
MaksMolokovozov	int	Maximum number of tankers to be admitted to the factory
VremyaMezhduMolokovozami	double	Time between tankers arrival
ProtsBrakaTary	double	Percentage of tare rejects
ProtsBrakaUpak	double	Percentage of packaging rejects
Variables of hardware–raw material shop		
ProizPriemki	double	Performance of raw milk acceptance unit
ProizPaster	double	Performance of pasteurizer
ProizSterel	double	Performance of sterilizer
VrZakvaski	double	Time required for starter preparation
VrFerm	double	Time required for product fermentation
VmestKhrSyrM	double	Capacity of raw milk storage
VmestKhrPastM	double	Capacity of pasteurized milk storage
VmestSmesit	int	Capacity of mixer
PrOkhSyrM	double	Performance of raw milk cooler
PrOkhPastM	double	Performance of pasteurized milk cooler
VrSmeshiv	double	Time required for mixer to process one tank
VmestEmFerment	int	Capacity of tank for fermentation
KolVoZakvaski	int	Amount of starters required for one fermentation tank
KolVKorobke	int	Number of packages in a box
VrDoSklada	double	Time of pallet transportation to storage
PrPodTary	double	Performance of tare preparation for packages
VesFasovki	int	Capacity of product package (1,000 g)
KolKorVPallete	int	Number of boxes on one pallet
PrFasovki	double	Performance of packing unit
KolvoTary	int	Number of packages required for 1 l of product
KolvoShtablerov	int	Number of stackers at store house

Table 1
Variables of production process model

At the next stage, it was required to represent the main structure of factory with interrelations of shops and flows of raw materials. The developed flow diagram of hardware–raw material shop is illustrated in Fig. 3. This diagram depicts delivery of raw materials to the factory in the form of milk tankers, which are subsequently connected to hardware–raw material shop (HRS). Then, in the HRS, according to the preset variables, products are obtained. When raw materials pass all the stages of HRS, finished products are packed and placed into boxes, the packing variables are preset in the model. It should be mentioned, that packages and tares are supplied only after delivery of finished products. Then the packed products are placed onto pallets which are supplied to store house and then to consumers.



Участок приемки сырого молока	Acceptance of raw milk
Фура	Truck
Участок стерилизованного молока и ферментированные продуктов	Site of sterilized milk and fermented products
Насос	Pump
Автоклав	Autoclave
Охладитель	Cooler
Заквасчик	Starter tank
Закваска	Starter
Участок розлива и упаковки	Filling and packing site
Участок доставки готового продукта до потребителя	Delivery of finished product to consumer
не соединен	not connected
Участок доставки и приема тары, упаковки	Delivery and acceptance of tare, packages
поступление паллет	Pallets
Молоковозы	Milk tankers
время пастеризации	pasteurizing time
время заквашивания	time of starter addition
фуры	Trucks

Figure 3
Stream diagram of HRS

The model is presented by the logics of structural processes running at food factories.

At the acceptance site, by means of the Fur, carMoveTo, carExit agents the logics of arrival of milk tankers is simulated.

The site of sterilized milk and fermented products is presented by a series of agents for product storage (Tank) and transport lines (pipeline) simulating flowing of finished products by pipes and their storage and processing in tanks. After termination of the process, the milk product is converted into kefir using mixer.

At the next stage, according to UML diagram of processes, the finished product is delivered to filling and packing site, where filling of kefir into tare is simulated and the finished product is prepared for transfer to the site of tare delivery and acceptance, where the finished product is placed onto pallets and transferred for delivery.

Therefore, the stream diagram of HRS simulates operation of equipment according to the above UML diagram. In addition, due to implementation of conventional operators upon initialization, correct forwarding of requests is performed, thus simulating production of various products.

The implemented model was verified for adequacy, when simulated results were compared with actual production; and at the next stage, series of simulation experiments were carried out to determine optimum variables of production process.

Results and Discussion

In order to obtain correct results during experiments, it is required to compare variables of each model object with actual production. In the considered case, the production line is equipped with Tetra Pack devices, hence, after performed analysis of engineering unit of this company, the following variables were selected being summarized in Table 2.

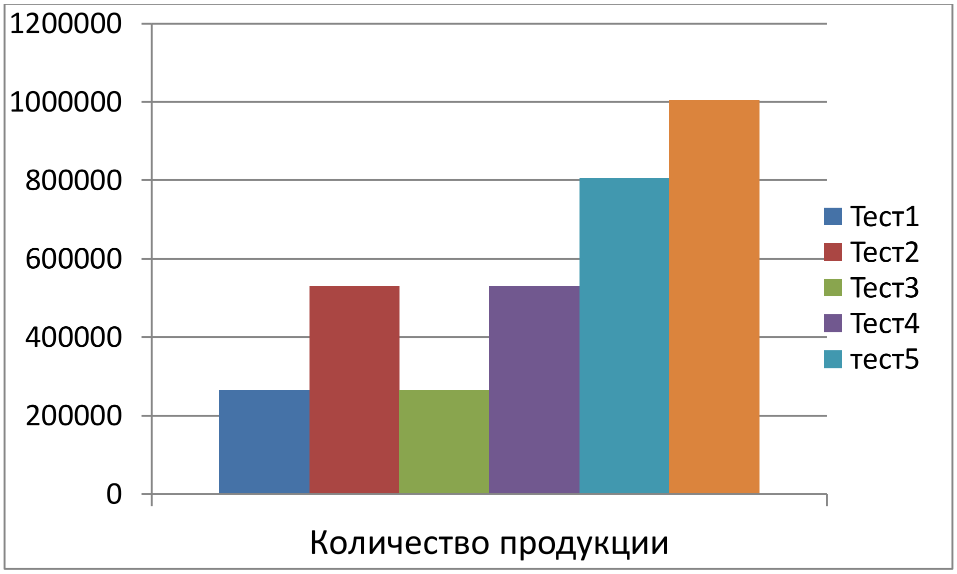
Object	Parameter	Value
Milk acceptance unit	Performance range	5,000-100,000 l/h
Pasteurizer	Performance range	5,000-20,000 l/h
Units for recombination and dissolution of powdered milk	Performance range	3,000-40,000 l/h
	Additives and Powdered milk	50/30 kg – 150/120 kg
Sterilizer	Performance range	1,500-30,000 l/h
Packer	Maximum performance	13,000 pack/h
Straw applicator	Maximum performance	18,750 pack/h
Stacker	Maximum performance	8,000 pack/h
Cream cooler	Performance range	1,000-3,000 l/h
Raw milk cooler	Maximum performance	25,000 l/h
Pasteurized milk cooler	Maximum performance	20,000 l/h
Cap applicator	Maximum performance	15,000 pack/h
Preparation of package	Maximum performance	13,000 pack/h

Table 2
Variables of model objects

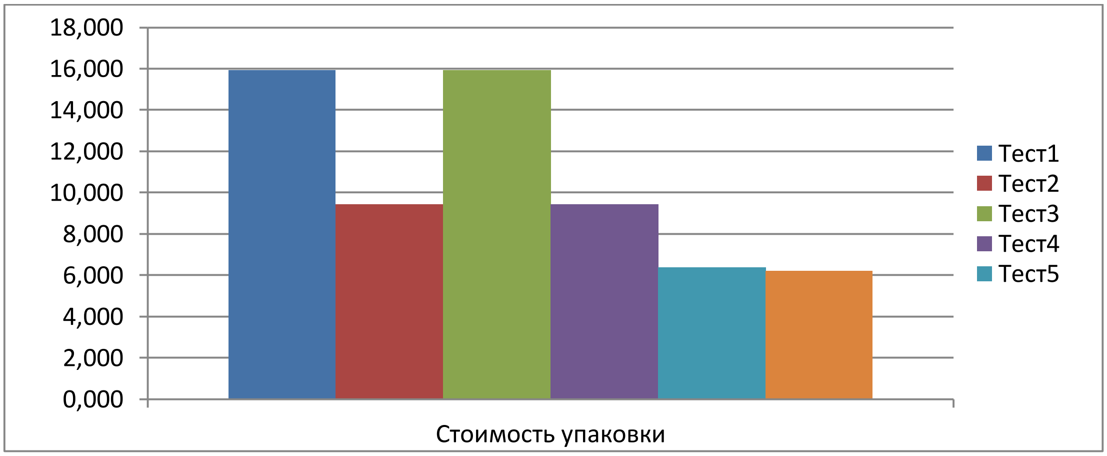
With known capabilities of engineering units[8], it is possible to perform experiments modifying these variables in the permitted range.

[8] V. V. Ilyukhin; I. M. Tambovtsev y M. Ya. Burlev, Montazh, naladka, diagnostika, remont i servis oborudovaniya predpriyatii molochnoi promyshlennosti (St. Petersburg: GIORD, 2006); V. B. Ponomarev y A. B. Loshkarev, Matematicheskoe modelirovanie tekhnologicheskikh protsessov

During simulations, a set of tests was carried out with varied package weight and rate of packing devices. It should be mentioned that the simulating time was restricted by 1,440 units, a unit of model time was one minute, thus, it was possible to estimate production capabilities per one day.



Тест	Test
Количество продукции	Amount of product



Тест	Test
Стоимость упаковки	Package cost

Figure 4
Diagrams of tests (amount of final product and packing cost)

(Ekaterinburg: UGTU–UPI, 2006) y P. L. Lisin; K. K. Polyansky y P. A. Miller, Sovremennoe tekhnologicheskoe oborudovanie dlya teplovoi obrabotki moloka i molochnykh produktov: pasterizatsionnye ustanovki, podogrevateli, okhladiteli, zakvasochniki: Reference book (St. Petersburg: GIORD, 2009).

On the basis of the experiments (Fig. 4), it was established that production capacity of filling and packing shop was sufficient to provide operation of the factory for processing of 342,000 l of raw material, which was equivalent to 57 milk tankers even upon decrease in performance of production units by one third of maximum value. In addition, on the basis of the experiments, it was revealed that upon products packing by 250 g, the stackers for products at store house were insufficient, as a consequence, a portion of profit was lost; thus, in the case of low packing weights, it had been recommended to increase the number of stackers to 10. The influence of filling and packing shops on financial indicators was insufficient.

Conclusion

On the basis of conceptual and formal description, the discrete-event model was developed; the operation of kefir production factory was analyzed using multi-agent simulation.

On the basis of the implemented model, using tools of simulation experiment, it was possible:

- to carry out various modifications in the factory structure and to analyze indicators of interest;

- to estimate operation of equipment and its performances, thus detecting bottlenecks of production line;

- to simulate modernization of production without significant expenses.

Using the developed simulation model, the experiments were performed in packing shop with subsequent recommendations for this shop. This method can be applied for generation of recommendations for other production shops, and the developed model can be applied for planning and management of kefir production.

References

Blagoveshchenskaya, M. M. y Zlobin, L. A. Informatsionnye tekhnologii sistem upravleniya tekhnologicheskimi protsessami. Moscow: Vysshaya shkola. 2010.

Boev, V. D.; Kirik, D. I. y Sypchenko, R. P. Komp'yuternoe modelirovanie: Guidebook. St. Petersburg: VAS. 2011.

Fajar, A. y Sarno, R. “Asynchronous agent-based simulation and optimization of parallel businesss”. Telkomnika (Telecommunication Computing Electronics and Control) Vol: 17 num 4 (2019): 1731-1739.

Gabrin, K. E. y Kozlova, E. A. Osnovy imitatsionnogo modelirovaniya v ekonomike i upravlenii: Guidebook. Chelyabinsk: YuUrGU. 2004.

Ilyukhin, V. V.; Tambovtsev, I. M. y Burlev, M. Ya. Montazh, naladka, diagnostika, remont i servis oborudovaniya predpriyatii molochnoi promyshlennosti. St. Petersburg: GIORD. 2006.

Ivashkin, Yu. A. y Nazoikin E. A. “Mul'tiagentnoe modelirovanie protsessa nakopleniya znanii”. Programmnye produkty i sistemy num 1 (2011): 47-52.

Karpov, Yu. G Imitatsionnoe modelirovanie sistem: vvedenie v modelirovanie s pomoshch'yu AnyLogic 5 (+ CD). St. Petersburg: BKhV-Peterburg. 2005.

Leonenko, A. V. Samouchitel' UML. St. Petersburg: BKhV-Petersuburg. 2004.

Lisin, P. L.; Polyansky, K. K. y Miller, P. A. Sovremennoe tekhnologicheskoe oborudovanie dlya teplovoi obrabotki moloka i molochnykh produktov: pasterizatsionnye ustanovki, podogrevateli, okhladiteli, zakvasochniki: Reference book. St. Petersburg: GIORD. 2009.

Nazoikin, E. A.; Blagoveshchenskii, I. G.; Blagoveshchenskaya, M. M. y Naumov, R. R. “Identifikatsiya protsessov proizvodstva marmeladnykh mass s ispol'zovaniem metodov imitatsionnogo modelirovaniya”. Pishchevaya industriya Vol: 1 num 39 (2019): 40-41.

Nazoikin, E. A.; Blagoveshchenskii, I. G.; Blagoveshchenskaya, M. M. y Naumov, R. R. Primenenie agentnykh tekhnologii v analize proizvodstvennykh protsessov pishchevykh proizvodstv, In: Advanced food technologies: status, trends, points of increase: proceedings. November 29-30, 2018.

Ponomarev, V. B. y Loshkarev, A. B. Matematicheskoe modelirovanie tekhnologicheskikh protsessov. Ekaterinburg: UGTU–UPI. 2006.

Sirota, A. A. Komp'yuternoe modelirovanie i otsenka effektivnosti slozhnykh sistem: Guidebook. Moscow: Tekhnosfera. 2006.

Sovetov, B. Ya. y Yakovlev, S. A. Modelirovanie sistem: Guidebook. Moscow: Vysshaya shkola. 2007.

REVISTA INCLUSIONES M.R.
REVISTA DE HUMANIDADES Y CIENCIAS SOCIALES

CUADERNOS DE SOFÍA EDITORIAL