Universidad Continental

FACULTAD DE INGENIERÍA

Escuela Académico Profesional de Ingeniería Industrial

Tesis

Productivity Improvement by Means of Method Engineering Tools and Automation in Ice Cream Production at Bonanza Company

Edgar Walter Menendez Elguera
Sofia Raymunda Aldana Fernández
Sebastian David Torres Sanchez
Rubén Darío Arzapalo Bello

Para optar el Título Profesional de
Ingeniero Industrial

Huancayo, 2023

Universidad Continental

INFORME DE CONFORMIDAD DE ORIGINALIDAD DE TESIS: EN FORMATO ARTÍCULO CIENTÍFICO

A	**:**	Felipe Néstor Gutarra Meza Decano de la Facultad de Ingeniería
DE	**:**	Rubén Darío Arzapalo Bello Asesor de tesis
ASUNTO	**:**	Remito resultado de evaluación de originalidad de tesis
FECHA	**:**	07 de Noviembre del 2023

Con sumo agrado me dirijo a vuestro despacho para saludarlo y en vista de haber sido designado asesor de la tesis titulada: "Productivity improvement by means of method engineering tools and automation in ice cream production at bonanza company ", perteneciente al/la/los/las estudiante(s) Edgar Walter Menendez Elguera, Sofia Raymunda Aldana Fernández ,Sebastian David Torres Sanchez, de la E.A.P. de Ingeniería Industrial; se procedió con la carga del documento a la plataforma "Turnitin" y se realizó la verificación completa de las coincidencias resaltadas por el software dando por resultado 15 % de similitud (informe adjunto) sin encontrarse hallazgos relacionados a plagio. Se utilizaron los siguientes filtros:

- Filtro de exclusión de bibliografía SI [ ] NO [X]
- Filtro de exclusión de grupos de palabras menores SI [ ] NO [X]
  (Nº de palabras excluidas:)
- Exclusión de fuente por trabajo anterior del mismo estudiante SI [X] NO [ ]

En consecuencia, se determina que la tesis en formato artículo científico constituye un documento original al presentar similitud de otros autores (citas) por debajo del porcentaje establecido por la Universidad.

Recae toda responsabilidad del contenido la tesis en formato artículo científico sobre el autor y asesor, en concordancia a los principios de legalidad, presunción de veracidad y simplicidad, expresados en el Reglamento del Registro Nacional de Trabajos de Investigación para optar grados académicos y títulos profesionales – RENATI y en la Directiva 003-2016-R/UC.

Esperando la atención a la presente, me despido sin otro particular y sea propicia la ocasión para renovar las muestras de mi especial consideración.

Atentamente,

Asesor de tesis

Cc.
Facultad
Oficina de Grados y Títulos
Interesado(a)

DECLARACIÓN JURADA DE AUTORÍA

El presente documento tiene por finalidad declarar adecuada y explícitamente el aporte de cada estudiante en la elaboración del trabajo de investigación a ser utilizado para la sustentación de tesis: formato de artículo científico.

Yo: Edgar Walter Menendez Elguera, con Documento nacional de identidad (DNI) N° 74296488; teléfono 963074357; estudiante de la Escuela Académico Profesional de Ingeniería Industrial.

Yo: Sofia Raymunda Aldana Fernández, con Documento nacional de identidad (DNI) N° 74651449; teléfono 985461316; estudiante de la Escuela Académico Profesional de Ingeniería Industrial.

Yo: Sebastian David Torres Sanchez, con Documento nacional de identidad (DNI) N° 72915339; teléfono 944250180; estudiante de la Escuela Académico Profesional de Ingeniería Industrial.

Yo: Rubén Darío Arzapalo Bello, con Documento nacional de identidad (DNI) N° 41058202; teléfono 937568220; Director de la Escuela Académico Profesional de Ingeniería Industrial.

Ante Usted, con el debido respeto me presento y expongo:
Declaramos que hemos participado en la ideación del problema, recolección de datos, elaboración y aprobación final del artículo científico.

Firma
DNI: 74296488

Firma
DNI: 74651449

Firma
DNI: 74651449

Firma del asesor
Rubén Darío Arzapalo Bello

Paper Aldana_ Menendez_Torres

INFORME DE ORIGINALIDAD

15%	10%	11%	8%
INDICE DE SIMILITUD	FUENTES DE INTERNET	PUBLICACIONES	TRABAJOS DEL ESTUDIANTE

FUENTES PRIMARIAS

1	cris.continental.edu.pe Fuente de Internet	2%
2	Iraiz Lucero Quintanilla-Mosquera, Jhon Rodrigo Ortiz-Zacarias, Sliver Ivan Del Carpio-Ramirez, Jesus Eduardo Rosales-Fierro et al. "Design of an automated manure collection system for the production of biogas through biodigesters", 2022 IEEE International IOT, Electronics and Mechatronics Conference (IEMTRONICS), 2022 Publicación	1%
3	Franco Callegati, Aldo Campi, Chiara Contoli, Silvio Di Santi et al. "SDN-based Differentiated Traffic Flow Management for Industrial Internet of Things Environments", 2021 IEEE Symposium on Computers and Communications (ISCC), 2021 Publicación	1%
4	www2.mdpi.com Fuente de Internet	1%

5	Submitted to University of Queensland Trabajo del estudiante	1 %
6	Submitted to University of Leeds Trabajo del estudiante	1 %
7	Submitted to University of Greenwich Trabajo del estudiante	1 %
8	repositorio.ucv.edu.pe Fuente de Internet	1 %
9	www.biorxiv.org Fuente de Internet	1 %
10	Submitted to Carnegie Mellon University Trabajo del estudiante	1 %
11	Nataliia Lutska, Lidiia Vlasenko, Nataliia Zaiets, Vitaliy Lysenko. "Modeling the Productivity of a Sugar Factory using Machine Learning Methods", 2022 IEEE 17th International Conference on Computer Sciences and Information Technologies (CSIT), 2022 Publicación	1 %
12	Submitted to Southampton Solent University Trabajo del estudiante	1 %
13	bm.kaznu.kz Fuente de Internet	1 %
14	www.sochob.cl	

	Fuente de Internet	<1 %
15	Submitted to South Bank University Trabajo del estudiante	<1 %
16	Xinyu Jing, Zihan Chen, Zonghui Tang, Yuting Tao et al. "Preparation of camellia oil oleogel and its application in an ice cream system", LWT, 2022 Publicación	<1 %
17	Submitted to Glasgow Caledonian University Trabajo del estudiante	<1 %
18	Submitted to Southern Cross University Trabajo del estudiante	<1 %
19	www.ijraset.com Fuente de Internet	<1 %
20	www.researchgate.net Fuente de Internet	<1 %
21	repository.tudelft.nl Fuente de Internet	<1 %
22	Submitted to Brigham Young University Trabajo del estudiante	<1 %
23	Shadman Sakib, Khan Md. Hasib, Ihtyaz Kader Tasawar, Abyaz Kader Tanzeem et al. "A Data-Driven Hybrid Optimization Based Deep Network Model for Short-Term Residential	<1 %

Load Forecasting", 2021 IEEE 12th Annual Information Technology, Electronics and Mobile Communication Conference (IEMCON), 2021
Publicación

---

24 Casiana Blanca J. Villarino, Heart Maryse A. Alikpala, Adrian F. Begonia, Janelle D. Cruz et al. "Quality and health dimensions of pulse-based dairy alternatives with chickpeas, lupins and mung beans", Critical Reviews in Food Science and Nutrition, 2022 <1 %
Publicación

---

25 Hatice Bekiroglu, Hamza Goktas, Dila Karaibrahim, Fatih Bozkurt, Osman Sagdic. "Determination of rheological, melting and sensorial properties and volatile compounds of vegan ice cream produced with fresh and dried walnut milk", International Journal of Gastronomy and Food Science, 2022 <1 %
Publicación

---

26 Manuella Oliveira Nascimento, Carla Vitória de Fátima Pereira Santos, Viviane Belini Rodrigues, Ernandes Rodrigues de Alencar et al. "Survival of Probiotic Lactic Acid Bacteria In Ice Cream During Storage: A Systematic Review", Research Square Platform LLC, 2023 <1 %
Publicación

Productivity improvement by means of method engineering tools and automation in ice cream production at bonanza company

Sofia Raymunda Aldana-Fernández
Department of Industrial Engineering
Universidad Continental
Huancayo, Perú
74651449@continental.edu.pe

Edgar Walter Menendez-Elguera
Department of Industrial Engineering
Universidad Continental
Huancayo, Perú
74296488@continental.edu.pe

Sebastian David Torres-Sanchez
Department of Industrial Engineering
Universidad Continental
Huancayo, Perú
72915339@continental.edu.pe

Ruben Dario Arzapalo-Bello
Department of Industrial Engineering
Universidad Continental
Huancayo, Perú
rarzapalo@continental.edu.pe

***Abstract*—The production of ice cream has become very popular in the last decade, showing a gradual increase in food consumption preference, generating millions of dollars in the international market, becoming a sector with great technological progress helping to improve the ice cream industry. Even so, there are companies that carry out the processes in an artisanal manner or with little technological modernization, as in the case of Bonanza. The objective of this article is to improve productivity through the use of method engineering tools and industrial automation in the production of the ice cream line of the Bonanza company. In a guided inspection, the operations diagram, process analysis and route diagram were determined. Finding dead times, bottlenecks, congestion and misuse of resources. With the help of Autodesk Inventor, Labview and TinkerCAD programs, the design and simulation of automated machines for the process of cleaning, inspection and weighing of fruit was carried out. This allowed to go from 30 min, 41 min and 65 min to 14 min and 20 minutes by merging the last two processes respectively. In addition to improving all internal processes and restructuring the path of the route. In conclusion, with the implementation of this project, the product execution time was reduced by 3 hours, optimal resources and increased productivity in the Bonanza company.**

Keywords— Methods engineering, productivity, automation, refrigeration industry.

I. INTRODUCTION

In the last decade, the production of ice cream has become increasingly famous, including those that maintain low levels of sugar or fat [1]. Since about five years ago, it has captured notoriety among Indonesians demonstrating the gradual increase, preference for ice cream food consumption and steady sales, in annual growth representing 5.3% growth from 2014 to 2019 period. Managing to increase the volume of the ice cream industry in 2018 by 60.1%, compared to the last two years with 48.9% and 54.4%, being driven by the low-income segment by 62%, due to new manufacturers offering low-end varieties in line with the pocket of the segment compared to high-end offered by market leaders. [2, 3]. Being the same manufacturers in the decision making in production, due to the analysis of sales of different types of ice cream in retail stores from the purchase videos of users [4]. In the summer season it is considered a popular dessert making the U.S. ice cream market to reach 7600 million dollars in 2021 and the world market to reach about 50 billion dollars year after year [5, 6].

Ice cream is a functional food with great potential because it can be fused with various fruits rich in phenols, probiotics and prebiotics. In addition, it is in great demand by consumers, since it can be consumed by people from 7 to 70 years of age in most countries of the world and is appreciated for its balanced food characteristics, delicious flavors, good nutritional properties and refreshing effect [7, 8, 3]. Recent analyses determined that the addition of mammalian milks in ice cream is a suitable food matrix for probiotics, containing rich sources of macro elements and for its high digestibility. With the help of natural antioxidants, they can replace artificial colorants to avoid producing allergic reactions [1].

Being a food processing sector, the level of hygiene should be relatively high, however, there are defects on the surface, the most common being blue spots, crust material and knot. The first defect is produced by the presence of fungi [9]. Currently, advanced technology is being implemented to improve the process in the ice cream industry, to remove traditional methods based on relay controls with simple and easy to control times obtaining very low precision and poor quality ice cream, by a simple control management causes the machines to be damaged or spoiled more easily obtaining ice cream with different consistency, hardness and flavor [10]. The field of intelligent or automated home appliances attracted much attention, improving the limits in industrial plants to the outside world. Through the very promising e-Maintenance service, it is possible to interact remotely with the refrigeration machines, allowing technicians to check configuration, update software modules, the current and past status. With this technology, it is possible to solve problems that occur in companies [11].

In a guided inspection carried out at the Bonanza company located in Jauja, which belongs to the Junín region of Peru. It is observed that the ice cream production line is still made manually or little industrialization, generating low productivity, bottlenecks and downtime in production. A very important point to increase the company's profits is to guarantee the planned

productivity through technological processes, whose final indicator is the production yield [12]. This article aims to implement automated processes to improve productivity in the Bonanza company, by means of methods engineering to identify bottlenecks and dead times, allowing to restructure the ice cream production line and optimize times with the help of technology.

II. MATERIALS AND METHODS

To achieve the optimization of time lapses in the ice cream production line of the company Bonanza, the Ishikawa diagram was used to know and establish the problem or effect to analyze, then performed an analysis with the help of the Methods Engineering, because it was observed bottlenecks along the process generating that these activities are not carried out efficiently, this technique reduces the work content of a process or operation to increase production. Likewise, VDI 2206 was used for the improvement proposal due to the implementation of a mechatronic design.

A. *Cause-effect diagram*

The Ishikawa diagram is used because it is a method that graphically shows the identification and solution of causes of an event, this scheme allows finding the initial origins of a problem in a structured way. Fig. 1 shows that there is a decrease in productivity in the ice cream production line, generating various scenarios that directly and negatively affect its production, as well as inadequate handling of materials, lack of raw materials, overtime, insufficient machine capacity. However, the main cause is the absence of a process or procedure manual and the lack of standardization of times.

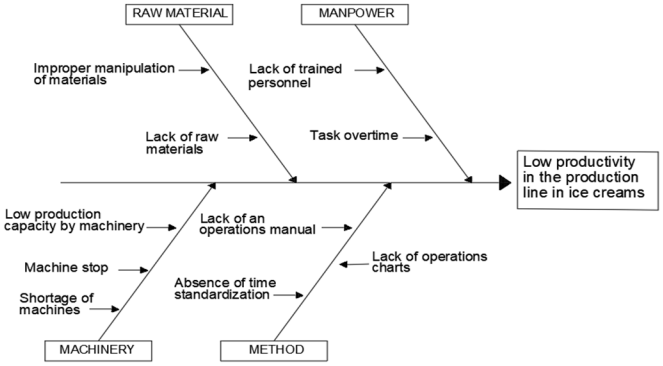

Fig. 1. Ishikawa Diagram of the ice cream production area - Bonanza.

B. *Methods engineering*

The purpose of the methods engineering approach is to optimize the processes, operations, tasks and including the design of instruments. Internally, industrial processes have activities that increase value to the process and those that cause costs; therefore, it is recommended that the latter be compressed to the maximum and, if feasible, eliminated [13].

The Bonanza company is recognized for its ice cream production services; however, it has deficiencies in the fruit weighing and inspection stage, creating a bottleneck that generates low productivity in the production line. From the engineering approach, the production process will be analyzed through the use of three movement study tools: process operation diagram (PDO), process analysis diagram (PDA) and stroke diagram (ST).

a) PDO: When using the operations diagram, whose purpose is to identify, inspect and operationalize a process from the entry of raw materials to the completion of the product, the ice cream production line lacks an optimal work structure in the operation of washing and inspection of fruits, which leads to delays and downtime, as shown in Fig. 2 and Fig. 3.

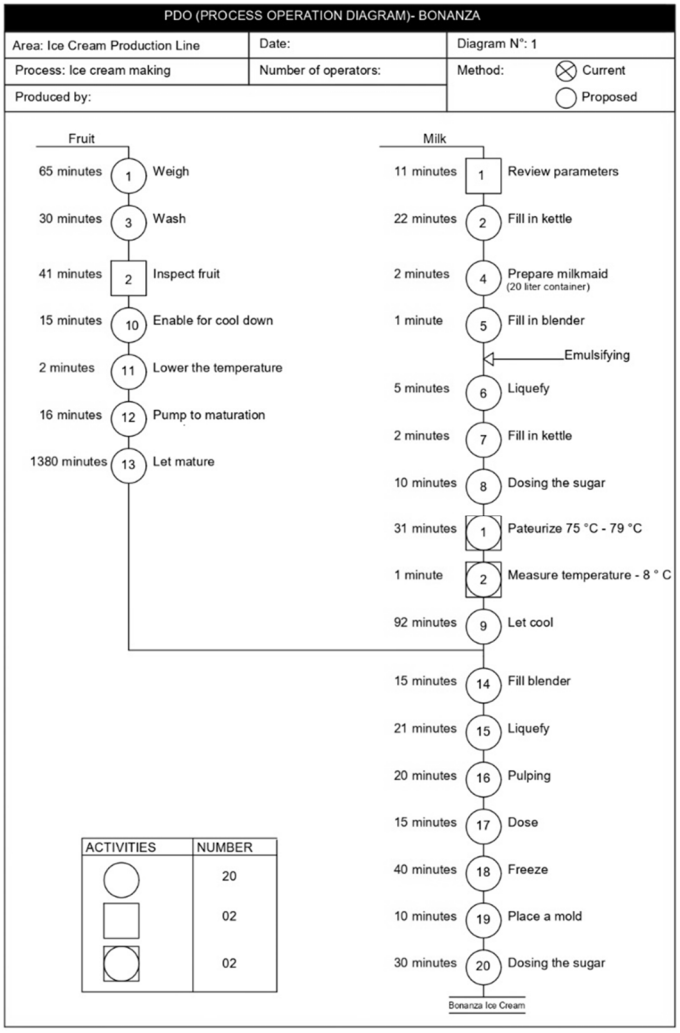

Fig. 2. PDO of the Bonanza ice cream production line.

b) PDA: The analytical process diagram details the operation, distance, transport, storage, delay, time, among others, that is used in a product to perform a more detailed analysis of the process. Currently the working method of the company Bonanza has unnecessary activities and repetitive operations which generates a low productivity, in Fig. 3. it is evident that the washing and inspection of fruits generate unnecessary delays that could be combined with a mechatronic design.

Identify applicable funding agency here. If none, delete this text box.

PAD	PROCESS ANALYSIS DIAGRAM	SUMMARY		
PROCESS:	Elaboration of ice creams of the company Bonanza	SYMBOL	ACTIVITY	CURRENT / %
COMPANY UNDER STUDY:	Bonanza		Operation	23 / 76.7%
			Transport	4 / 13.3%
			Wait / Delay	0 / 0.0%
			Inspection	2 / 6.7%
			Storage	1 / 3.3%
		Total activities carried out		30 / 100.0%
		TD = Total Distance (m)		43.8 meters
		ST = Standard Time (min/h)		1,899 Min/H

Participants	DESCRIPTION OF ACTIVITIES	TD (m)	ST (min)	SYMBOLS	OBSERVATION
Operator 1	Milk analysis	-	11.0		Check parameters
Operator 1	Filling in kettle	-	22.0		
Operator 2	Heavy fruit	-	65.0		Balance BA-1
Operator 2	Fruit w ash	-	30.0		Use of filtered w ater
Operator 3	Fruit inspection	-	41.0		
Operator 2	Take to cold room	20.0	15.0		
Operator 1	Take out bucket of milk from kettle	-	2.0		
Operator 2	Decrease temperature	-	2.0		
Operator 1	Place in blender	-	1.0		
Operator 1	Place Emulsifier- Stabilizer	-	1.0		
Operator 4	Liquefy	-	5.0		LI-1 blender
Operator 1	Place in kettle	-	2.0		
Operator 4	Dose sugar	-	10.0		
Operator 4	Take to pasteurized area	-	6.0		
Operator 4	Pasteurize milk	-	31.0		Temperature 75°C
Operator 3	Inspect temperature	-	1.0		
Operator 4	Let cool	-	92.0		Temperature 6-8°C
Operator 3	Take temperature	-	2.0		
Operator 4	Pumping to maturation	5.0	16.0		
Operator 4	Allow to mature Broth	-	1380.0		Temperature 6-8°C
Operator 1	Take to smoothie	2.5	15.0		
Operator 4	Blend base broth	-	21.0		LI-1 blender
Operator 4	Pulping	-	20.0		DE-1 pulper
Operator 2	Dosage	-	15.0		
Operator 3	Freezing	-	40.0		Ice cream machine in chloride concentration
Operator 3	Transport to the packing area	-	7.0		
Operator 4	Raise draw ers	-	6.0		
Operator 2	Demolding	-	10.0		Temperature -40°C
Operator 2	Sheath and seal	-	20.0		
Operator 2	Stored	-	10.0		
		27.5	1899	23 4 0 2 1	

Complementary Annotations:
This analytical process diagram represents a constantly changing procedure w ith opportunities for improvement.

Fig. 3. PDA actual Bonanza ice cream production line.

c) ST: The route diagram is a scheme of the organization of the plant floor plan where the production activities of the PDA are carried out. The layout of the Bonanza's floor plan presents an inefficient structure distribution because it generates congestion and delay in the transportation of the operators, as shown in Fig. 4.

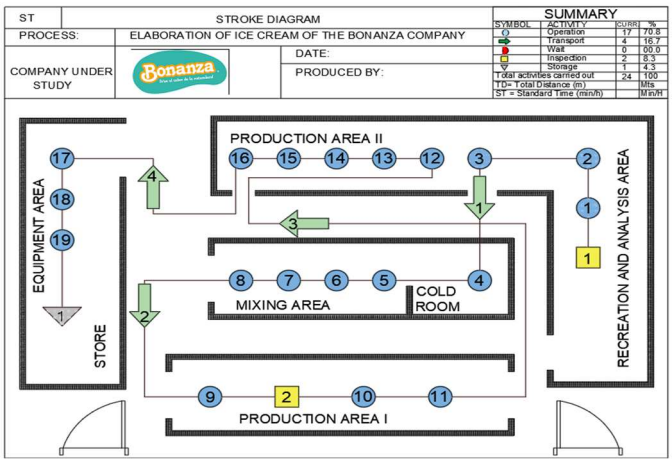

Fig. 4. Current ST of the Bonanza ice cream production line.

Identify applicable funding agency here. If none, delete this text box.

C. *Management indicators*

In order to estimate productivity, reference was made to the book Estudio del trabajo: Ingeniería de métodos y medición del trabajo [14] where it mentions that productivity is given by the product of efficiency and effectiveness; equation (1), shows the general model.

$$Productivity = Efficiency\ x\ Efficacy \quad (1)$$

Efficiency is the useful time in relation to the scheduled time as shown in equation (2), and efficacy is also related to the achievement of the proposed objectives as shown in equation (3).

$$Efficiency = \frac{Useful\ time}{Scheduled\ time} \quad (2)$$

$$Efficacy = \frac{Liters\ produced}{Programmed\ liters} \quad (3)$$

D. *Mechatronics regulations*

The VDI 2206 standard is applied for mechatronic systems due to the complexity, interdisciplinarity and heterogeneity containing data interfaces with components and devices that is currently on the rise. The standard in 2021 supports the development of process structuring with an extended V-model aspect, detailing the processes from requirements to delivery for use. In addition, the guideline does not have specification of methods or tools to be used, leaving the reader to make a deduction approach, achieving better definitions and cost estimates of the project. The methodology is performed in 4 phases to perform simulation, modeling and prototyping [15].

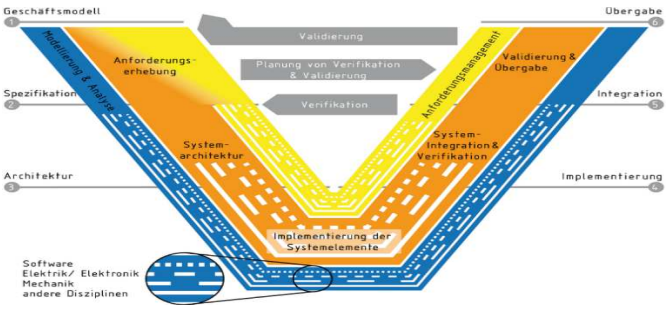

Fig. 5. VDI 2206 mechatronics standard.

III. Results

The following results were obtained by applying methods engineering in the Bonanza company, improving productivity and process in an automated way in the bottlenecks and dead times found.

A. *Design of automated machines*

With the help of the program Autodesk Invertor Professional, automated machines were designed for the transport, washing, inspection, weighing and selection of optimal fruits for the production of ice cream line in the company Bonanza.

At the beginning of the production line, a metal tray was designed for storing the fruit. Once production is started, a vertical conveyor belt carries the product individually by means of its pallets, allowing the separation to carry out the other processes correctly and prevent the fruit from falling over the

sides because it is agglomerated. Once the fruit is individually placed, it is transported to the next process by means of the blue conveyor belt, as shown in Fig. 7.

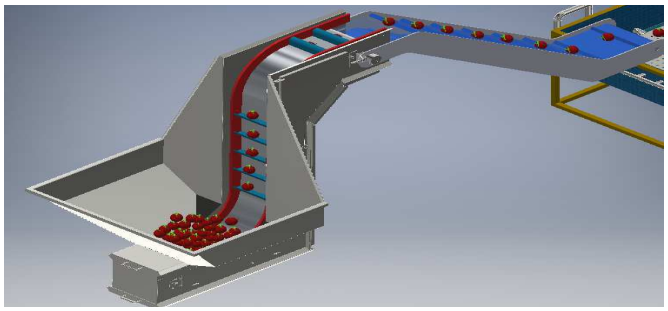

Fig. 6. Design of elevating conveyor for fruit separation.

The second automated process is the washing and drying of the fruit by means of water pressure, achieving to enter the product and when falling into the machine, by means of water pipes an amount of water is introduced into a well to remove simple impurities so as not to splash in case it is dirty with mud or other simple impurities. In the superior part of the exit conveyor belt the red pressure pipes are observed to make the final cleaning, by means of pressure jets to be able to give a deep cleaning and all this water can be poured to the well, with the help of the green drainage in Fig. 8 the excess of water is extracted and by means of a pumping system every certain time or impurities detected in the water.

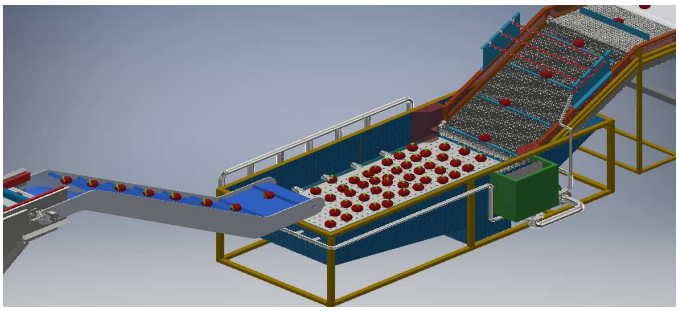

Fig. 7. Design of automated machine for fruit washing.

Once the fruit is free of impurities on the side of the belt, turbines are activated to dry the fruit quickly and then it is passed to the white conveyor belt to be inspected and weighed, separating the good and bad quality fruit. The latter is removed when the red light is turned on to a side box for the personnel to discard it, while the good fruit as shown in Fig. (9). Obtaining all these data smoothly and without delays helps to solve the bottleneck encountered.

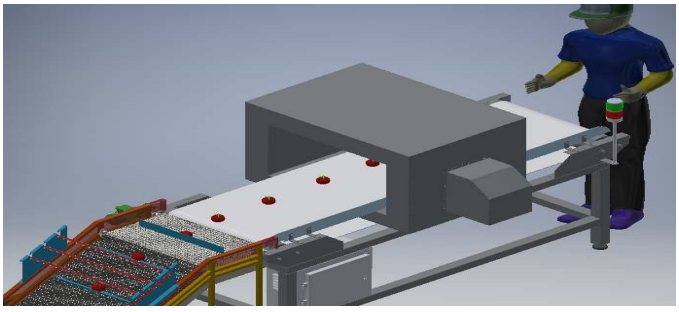

Fig. 8. Design of automated machine for inspection and weighing of fruits.

B. *Process automation*

An HMI environment developed in LabVIEW software was designed to supervise the automated process, as well as to obtain estimated cleaning, weighing and inspection times for each fruit. The first and last subprocess will be developed in collaboration with personnel who will observe the product inside the lead box in real time using cameras Fig. 9. Otherwise, if any of these two is incorrect, a red light will turn on to warn the picking collaborator and separate it from the process. Fig. 10 shows the implemented HMI environment detailing 3 data (cleanliness, consumable and weight) and the control of 4 cameras at different angles.

Fig. 9. HMI of the fruit washing, inspection and weighing process.

To obtain the weight was simulated in the TinkeCAD program, with the help of a force sensor obtaining results in Newtons, which when divided by gravity we obtain the Mass (Kg) of each fruit. This value is entered to the HMI interface obtaining all the data for the ice cream line process. Fig. 11 shows the programming and the electronic circuit. However, as it is implemented in a real way, industrial components must be used in order to obtain more accurate data.

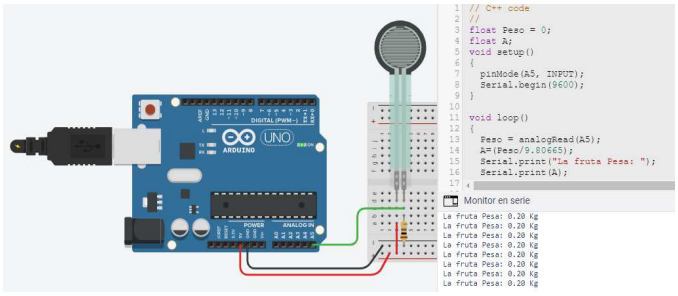

Fig. 10. Simulation of the force sensor for fruit weight in TinkerCAD.

For the washing process a time of 8sec per fruit was obtained and for the inspection-weighing process a time of 12sec was obtained. For the same quantity of fruit (100 units), a total of 14 minutes and 20 minutes, respectively, was obtained. The first process was reduced by 16 minutes and the second by 75 minutes, since the inspection and weighing process was combined by automation.

C. *Comparison of DAP proposals*

By means of the proposal of the current DAP, it was proposed to make certain changes in repetitive operations as shown in Fig. 4; the combination of washing and weighing-inspection activities was carried out using the automation

machine, so that the execution time has a reduction of approximately 3 hours per day as shown in Fig. 12.

PAD	PROCESS ANALYSIS DIAGRAM			SUMMARY			
PROCESS:	Elaboration of ice creams of the company Bonanza			SYMBOL	ACTIVITY	CURRENT	%
					Operation	17	70.8%
					Transport	4	16.7%
					Wait / Delay	0	0.0%
COMPANY UNDER STUDY:	Bonanza				Inspection	2	8.3%
					Storage	1	4.2%
				Total activities carried out		24	100.0%
				TD = Total Distance (m)		44	Metros
				ST = Standard Time (min/h)		1,693	Min/H
Participants	DESCRIPTION OF ACTIVITIES	TD (m)	ST (min)	SYMBOLS			OBSERVATION
Operator 1	Milk analysis	-	10				Check parameters
Operator 1	Filling in kettle	-	21				
Operator 2	Heavy fruit	-	14				Automated
Operator 2	Fruit w eighing and inspection	-	20				Automated
Operator 2	Take to cold room	21.3	14				
Operator 1	Place in blender	-	1				
Operator 1	Place Emulsifier- Stabilizer- Sugar	-	7				
Operator 4	Liquefy	-	5				LI-1 blender
Operator 1	Place in kettle	-	1				
Operator 3	Take to the pasteurized area	6.0	6				
Operator 4	Pasteurize milk	-	31				Temperature 75°C
Operator 3	Inspect temperature	-	1				
Operator 4	Pumping to maturation	6.0	16				
Operator 4	Allow to mature Broth	-	1380				Temperature 6-8°C
Operator 1	Take to smoothie	2.5	15				
Operator 4	Blend base broth	-	20				LI-1 blender
Operator 4	Pulping	-	19				DE-1 pulper
Operator 2	Dosage	-	15				
Operator 3	Freezing	-	40				Ice cream machine in chloride
Operator 2	Transport to the packing area	8.0	8				
Operator 3	Raise draw ers	-	6				
Operator 2	Demolding	-	10				Temperature -40°C
Operator 2	Sheath and seal	-	22				
Operator 2	Stored	-	10				
		43.8	1693	17	4	0	2 1
Complementary Annotations:							
This analytical process diagram represents a constantly changing procedure w ith opportunities for improvement.							

Fig. 11. Improved "PDA" of the Bonanza ice cream production line.

D. Improve the Bonanza company's route diagram

In order to improve the Bonanza company's route shown in Fig. 5, changes were made to the analytical process diagram, taking into consideration the continuity of production area I, cold storage room and production area II to make the best use of space as shown in Fig. 13, and at the same time optimize production time.

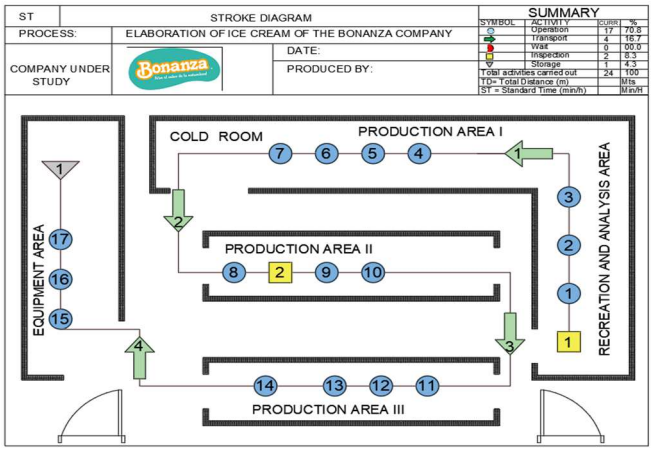

Fig. 12. Improved "ST" of the Bonanza ice cream production line.

Productivity was determined using the aforementioned formulas from the database obtained, as shown in Table I. Before the research, productivity was 76.36% and with the implementation, 86.97% was obtained, improving by 10.61%.

TABLE I. DATA FOR THE PRODUCTIVITY OPTION BEFORE AND AFTER THE INVESTIGATION

Production indicators	*Before*	*After*
Quantity produced	4000 Lt	4100 Lt
Scheduled quantity	4400 Lt	4400 Lt
Useful time	75.6 h	84 h
Total time	90 h	90 h
Efficiency	90.91 %	93.18 %
Efficacy	84 %	93.33 %
Productivity	76.36 %	86.97 %

IV. CONCLUSIONS

This research work made a proposal for engineering improvement in the optimization of processes in the production of ice cream, since according to the Ishikawa diagram it was required to supply the problem of low productivity, so methods engineering was applied using flow diagrams such as DAP and DOP to identify the presence of unproductive and dead times. In this document, activities such as fruit weighing-inspection were optimized through the design of the automated machine, seeking to generate a reduction in time and shortening work movements.

With the design software, the simulated automation process for obtaining times and the infrastructure of the machines was shown. In addition, the incorporation of the HMI environment for the quick interaction of the personnel in charge of the area with the machine for the respective inspection and monitoring.

Thanks to the route diagram it was possible to elaborate systematic instructions that specify the places, likewise there is a better use of spaces which avoids congestion in the workers, also the route of the facilities of the company has an optimal design of continuity in the areas of production and cold storage room.

By means of industrial automation, process times were optimized, achieving a reduction of 3 hours in execution and increasing productivity from 76.36% to 86.97% in the ice cream production line of the Bonanza company, allowing work to be done with greater productivity and making the most of resources. Being an automated process allows to have a clear and precise control, having a control of the production compared to the traditional way that was done, generating higher costs and more resources man-hours.

CKNOWLEDGMENT

Thanks to the Peruvian company Bonanza, for carrying out the guided inspection and providing the production data to perform improvement diagnostics for process automation through methods engineering. In addition, recognition to Universidad Continental, for providing the necessary knowledge for the development of research and projects in the engineering area.

REFERENCES

[1] U. Pankiewicz, M. Góral, K. Kozłowicz, and D. Góral, "Application of pulsed electric field in production of ice cream enriched with probiotic bacteria (L. rhamnosus B 442) containing intracellular calcium ions," J Food Eng, vol. 275, Jun. 2020, doi: 10.1016/j.jfoodeng.2019.109876.

[2] G. T. Komala and A. A. Agus, "Information Technology Systems in Supporting Outbound Logistics: Study of Low-End Ice Cream Distribution Business in Indonesia," 2020 3rd International Conference on Computer and Informatics Engineering (IC2IE), Yogyakarta, Indonesia, 2020, pp. 230-235, doi: 10.1109/IC2IE50715.2020.9274598.

[3] W. K. Wardhani, A. F. Lu'Ayi and H. H. P. Fatima, "Potential Reducing CO2 Emission for Ice Cream Industry through Energy Efficiency Improvement in Indonesia," 2019 IEEE 3rd International Conference on Green Energy and Applications (ICGEA), Taiyuan, China, 2019, pp. 183-187, doi: 10.1109/ICGEA.2019.8880772.

[4] J. Ma and Y. Jiang, "Improved Ice Cream Detection Algorithm Based on YOLOv5," 2022 International Conference on Machine Learning and Intelligent Systems Engineering (MLISE), Guangzhou, China, 2022, pp. 167-171, doi: 10.1109/MLISE57402.2022.00040.

[5] X. Jing *et al.*, "Preparation of camellia oil oleogel and its application in an ice cream system," *LWT*, vol. 169, Nov. 2022, doi: 10.1016/j.lwt.2022.113985.

[6] J. Paglia, C. Fung, and C. K. Yeung, "Milk protein concentrate and reduced-calcium milk protein concentrate as natural emulsifiers in clean label high-protein ice cream manufacture," *Journal of Future Foods*, vol. 3, no. 2, pp. 175–182, Jun. 2023, doi: 10.1016/j.jfutfo.2022.12.009.

[7] J. Paglia, C. Fung, and C. K. Yeung, "Milk protein concentrate and reduced-calcium milk protein concentrate as natural emulsifiers in clean label high-protein ice cream manufacture," *Journal of Future Foods*, vol. 3, no. 2, pp. 175–182, Jun. 2023, doi: 10.1016/j.jfutfo.2022.12.009.

[8] H. Bekiroglu, H. Goktas, D. Karaibrahim, F. Bozkurt, and O. Sagdic, "Determination of rheological, melting and sensorial properties and volatile compounds of vegan ice cream produced with fresh and dried walnut milk," *Int J Gastron Food Sci*, vol. 28, p. 100521, Jun. 2022, doi: 10.1016/J.IJGFS.2022.100521.

[9] Q. Chang, Y. Zhang and Z. Sun, "Research on Surface Defect Detection Algorithm of Ice-cream Bars Based on Clustering," 2019 IEEE 3rd Information Technology, Networking, Electronic and Automation Control Conference (ITNEC), Chengdu, China, 2019, pp. 537-541, doi: 10.1109/ITNEC.2019.8729001.

[10] D. Shuyu, C. Huanyu and Z. Linqi, "Application of Data Fusion Technology in Ice Cream Control System of Pouring Model," 2020 19th International Symposium on Distributed Computing and Applications for Business Engineering and Science (DCABES), Xuzhou, China, 2020, pp. 170-173, doi: 10.1109/DCABES50732.2020.00052.

[11] A. Corradi et al., "Smart Appliances and RAMI 4.0: Management and Servitization of Ice Cream Machines," in IEEE Transactions on Industrial Informatics, vol. 15, no. 2, pp. 1007-1016, Feb. 2019, doi: 10.1109/TII.2018.2867643.

[12] N. Lutska, L. Vlasenko, N. Zaiets and V. Lysenko, "Modeling the Productivity of a Sugar Factory using Machine Learning Methods," 2022 IEEE 17th International Conference on Computer Sciences and Information Technologies (CSIT), Lviv, Ukraine, 2022, pp. 353-356, doi: 10.1109/CSIT56902.2022.10000571.

[13] G. Bocángel et al., Ingeniería Industrial- Ingeniería de Métodos I, Primera ed., G. Bocángel, Ed., Huánuco: La Biblioteca Nacional de Perú N°: 2021-10219, 2021.

[14] R. García, Estudio del trabajo: Ingeniería de metodos y medición del trabajo, 2ª ed. Mexico: McGraw Hill, 2005.

[15] "VDI 2206 | VDI." https://www.vdi.de/richtlinien/programme-zu-vdi-richtlinien/vdi-2206 (accessed Jun. 28, 2022).

[16] S. I. Del Carpio Ramirez, J. R. O. Zacarias, J. B. M. Vazquez, S. A. C. Quijano and D. Huamanchahua, "Comparison Analysis of FIR, ARX, ARMAX by Least-Squares Estimation of the Temperature Variations of a Pasteurization Process," 2021 IEEE 12th Annual Ubiquitous Computing, Electronics & Mobile Communication Conference (UEMCON), New York, NY, USA, 2021, pp. 0699-0704, doi: 10.1109/UEMCON53757.2021.9666649.

[17] I. L. Quintanilla-Mosquera et al., "Design of an automated manure collection system for the production of biogas through biodigesters," 2022 IEEE International IOT, Electronics and Mechatronics Conference (IEMTRONICS), Toronto, ON, Canada, 2022, pp. 1-6, doi: 10.1109/IEMTRONICS55184.2022.9795763.

[18] Y. S. Valenzuela-Lino, Y. Rojas-Tapara, J. R. Ortiz-Zacarias, S. Ivan Del Carpio-Ramirez, F. W. Zarate-Peña and C. Coaquira-Rojo, "Automated design of a cleaning machine and an environmental temperature controller for guinea pig houses," 2022 IEEE International IOT, Electronics and Mechatronics Conference (IEMTRONICS), Toronto, ON, Canada, 2022, pp. 1-5, doi: 10.1109/IEMTRONICS55184.2022.9795767.

[19] J. Diego Aguirre Cangalaya, J. Antonio Cruz Anchiraico, S. Ivan Del Carpio Ramirez, S. Angel Chamorro Quijano and D. Huamanchahua, "Design of Haptic Vibrational Feedback Control in Upper Extremity Myoelectric Prostheses," 2022 8th International Conference on Mechatronics and Robotics Engineering (ICMRE), Munich, Germany, 2022, pp. 55-59, doi: 10.1109/ICMRE54455.2022.9734101.

[20] J. R. O. Zacarias, Y. C. Sullca-Mendoza, Y. S. Valenzuela-Lino, S. I. Del Carpio-Ramirez, N. Moggiano and C. Coaquira-Rojo, "Simulation of an Automated Tahitian lemon grading system based on computer vision," 2022 IEEE 13th Annual Ubiquitous Computing, Electronics & Mobile Communication Conference (UEMCON), New York, NY, NY, USA, 2022, pp. 0283-0289, doi: 10.1109/UEMCON54665.2022.9965667.

[21] R. M. Olivera-Pérez, T. Leticia Julcarima-Coca, J. R. Ortiz-Zacarias, I. Lucero Quintanilla-Mosquera, S. I. Del Carpio-Ramirez and J. James Hinostroza-Yucra, "Mechatronic design of a Stewart platform as a base isolator with an active control system," 2022 IEEE 13th Annual Ubiquitous Computing, Electronics & Mobile Communication Conference (UEMCON), New York, NY, NY, USA, 2022, pp. 0336-0341, doi: 10.1109/UEMCON54665.2022.9965713.