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Original Article

Design and Implementation of an Encoder Weighing System for Optimization in a Sausage Processing Plant

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Abstract *- Currently, some companies still use traditional weighing systems, constantly encountering problems that worsen their development. One of the main problems it usually shows is the lack of correct identification of the products that enter and leave a factory, in which it is considered essential to propose a more optimal design to speed up the registration of products and substantially improve productivity. That is why, in this research work, the implementation of an encoder weighing system is proposed for the optimization of a sausage processing plant, which will be shown with weighing software that will record the daily or monthly productivity according to the client's needs. The proposed system is made up of a 304 stainless steel electronic scale, a model TP9001 indicator with IP66 protection and an SBARCO model T4 labeler. This last device will work by means of thermal transfer with polypropylene tape in order to obtain a label resistant to humidity since basic frozen products will be used. As a result, it was obtained that the design of the weighing system was very effective in its implementation because it improved the final productivity of the packaging and labeling of the products by 98%. On the other hand, it is concluded that the project carried out would benefit any type of company since the system can work in various types of environments; In addition, its implementation is not complex, and its cost is accessible in terms of advantages and differences from other systems.*

Keywords *- Coder, Weighing, System, Polypropylene tape, Labeler.*

1. Introduction

Automation, control and supervision are very important factors for various business sectors in the global context of modernization. In fact, control and automation are fundamental parts of monitoring electronic devices that perform functions or work more efficiently to optimize a process [1,2]. In which if we focus on the productive sector, one can see the various shortcomings that exist when using traditional weighing systems and inadequate coding equipment for weight control and labeling in the various industrial sectors of South America [3].

Currently, in Colombia, Bolivia and Ecuador, some industrial sectors continue to use modern or digital scales, which are limited to carrying out a single activity, which is weighing, which is very alarming since today, a weighing system has several functions that are not being used in the best way, increasing the delay in productivity or the weighing process according to the activity [4,5]. In the same way, it happens with the labellers that, although it is true that there are various brands and models they offer in the international market, there are few devices that are economically accessible and have the availability of being linked to a digital weighing system. , since most labellers or encoders are designed to work directly with a computer and not with an electronic scale [6, 7].

This problem can be seen reflected in the Peruvian industry since today, traditional systems, such as mechanical scales, are still applied in various sectors despite being a long-lived technology. However, in less quantity, due to that today, there are electronic or digital weighing systems, which have many more advantages in terms of precision, functions and ease of use. [8]. Likewise, digital scales, despite their advantage in the Peruvian market, are not being used correctly, and this can be seen in the food, pork and vaccine industry in Peru, where in many cases, the user considers an inoperative device to the electronic balance that does not generate a correct weight, and this is due to the lack of inspection or periodic calibration that these devices require to maintain the possible accuracy and precision [8, 9].

That is why, seeing this problem, this research paper proposes the criteria that should be used to implement a coded weighing system in the meat food industry. For this, a company dedicated to the production of sausages will be taken as the study area, in which it had its facilities, due to the fact that a technical inspection was previously carried out. It was concluded that the weighing system of the dispatch area should be improved since it is indicated that there is a deficiency in the control and the labeling process of the products offered by the sausage company.

Thus, this research aims to provide a solution with a versatile, economic and easy-to-use system that seeks to optimize time, a fundamental factor in this industry. For this, a weighing system is proposed with the standards of a CLASS III scale, with IP66 protection, because the environment where it is proposed to be installed is highly humid. Likewise, for the labelling proposal, it is essential that the equipment works with polypropylene tape since it is resistant to humidity and liquids, among other materials, which maintains the established data of the products to be labeled. In addition, the system will have weighing software designed to display the daily input and output control of the products to be monitored.

This work is structured as follows: in section 2, we will talk about the literature review; In the same way, section 3 will focus on the methodology, where the design, the devices to be used in the installation, the operation and the advantages of the weighing system will be explained. In section 4, the results and discussions will be evidenced, and finally, in section 5, the conclusions will be indicated, as well as the recommendations of the research work.

2. Literature Review

Today, various electronic weighing systems are used in various industry areas. In which, they are applied according to the needs of the company since this electronic equipment has various functions to optimize a process, such as the use of a database and the Internet of Things, among other very interesting topics. That is why, in this section, several research works related to the proposed topic regarding the encoder weighing system will be reviewed.

In this article [11], the author indicates that in Colombia, in the department of Nariño, there is a lot of artisanal breeding of animals of small species, in which a certain town stands out for the breeding of guinea pigs, with an average of 20,000 artisan farms that need the lack of technology. For this reason, it proposes the implementation of an automated weighing and identification system, which allows monitoring the weighing of these animals without much human intervention, since the purpose of this system is to keep the animal's health in good condition because previously, the scales traditional ones generated injuries among other shortcomings. The system was designed based on 4 load cells, an RFID device for animal tracking, an ARDUINO platform for data processing, an LCD screen and SD memory to store the animal record. After the implementation, he concluded that when comparing a traditional system with the proposed weighing system, he obtained a mean absolute error of +-87.7 grams, which is 6% as a percentage. Likewise, he fulfilled the expectation of less animal handling with respect to the manual weighing process.

As a second point, in the thesis [12], the author proposes the implementation of an electronic scale for the monitoring of cattle fattening "ML Simbrah", in which, for the company, the correct control and monitoring of its animals from the moment they are born until they are sold to breed. The main problem determined by the author was the lack of a scale that allows meeting the needs of livestock since, in recent times, it has caused the sale of animals by estimating weights or also the transfer of animals to a collection center. For this reason, the author proposes a system that works with a mobile application and a display screen composed of the ARDUINO platform, an HC 05 Bluetooth module, and load sensors that will weigh a maximum of 1.5 Tn. In which as a result, he obtained favorable data showing an MAE error of 4%; In addition, the communication by Bluetooth and the application are satisfactory as long as the communication distance allowed by the wireless device is respected.

As a third point, in the article [13], the authors design and implement a volumetric system to improve the dispatch process of the company Orionlogistics, which is dedicated to the transportation of national and international cargo located in Quito, Ecuador and Tumbes. Peru. The main component of the design is a PLC, volumetric sensors to measure package size, 200Kg load cell, JSN-SR04T ultrasonic sensor, NEMA 17 stepper motor and A488 motor driver. Additionally, it implemented software that allows to visualize the information and sends the data to a standard labeler. On the other hand, the results obtained from the system confirm that the machine has an efficiency of 98% with a resolution of ±0.05 kg and ±1 cm.

Similarly, in article [14]. The author proposes a study to evaluate the growth efficiency of bovine cattle for 120 days to 60 cows that have an average weight of 350 to 400Kg. For this, the focus is placed on analysing and processing the collection of weighing data through identification based on RFID connected through the Internet of Things. This design system was implemented at a local cattle farm in Northern Thailand using a suitable technological context. The result shows a positive development of the system according to the benefit analysis of the cow weighing line and the chain process.

In the same way, the article [15] mentions that the greatest demand for electronic scales is applied mostly in greengrocers, sanitary industries, and especially to measure tiny things. For this, the author proposes a wireless electronic scale designed with an MSP430 controller and a ZigBee wireless module. In which, he used Visual Basic to develop the user interface for generating invoices and checking the network's performance using NetSim.

Obtaining results, such as the synchronization of data from a greater number of nodes and effectively receiving intelligent billing through ZigBee, in the same way, data loss and overload in various scenarios were with less than 2% error.

Finally, we know that today there are static and dynamic weighing systems used in various industries worldwide. Both static and dynamic systems have their advantages and disadvantages, as the article [16,17] comments, where it focuses mostly on solving the improvement of the precision of weighing systems in motion that are commonly applied in truck weights. To do this, the author proposes to increase the number of axle load sensors where they used two evaluation criteria, such as the relative error of 95% percent and the reliability characteristic.

In summary, it was seen that the authors have contributed to developing various designs of static and dynamic weighing systems using devices and tools to improve the industry's flow. However, to believe this initiative to optimize processes could be improved with low-cost and easy-to-install encoder weighing systems. In which in this article, the design of a coding system for a sausage and meat products plant is proposed, where various shortcomings and observations were found that will be detailed in the following section.

3. Methodology

This section will be a proposal that we will classify according to the different areas of interest, which develops each part of the segmentation of the criterion used for implementing an encoder passage system.

3.1. Study Area

The study area is located in the southern cone of Lima, located in the Mz. Yes, a lot. 5 Asc. The carnations of Lurín. In which, it is a process plant with more than 3 years in the Peruvian market. Dedicated to the elaboration of processed products and the sale of select cuts of pork and beef, with more than 60 products offered to the Peruvian market. Currently, it has been continuously implementing the application and development of advanced technology, which has allowed it to be one step ahead of its competitors and thus successfully satisfy the needs and desires of consumers. Therefore, the company accepted the proposal to implement the encoder weighing system to optimize the process in the dispatch area where the proposed device will be located.

3.2. System diagram and component description.

The flowchart of the proposed encoder weighing system is given as follows:

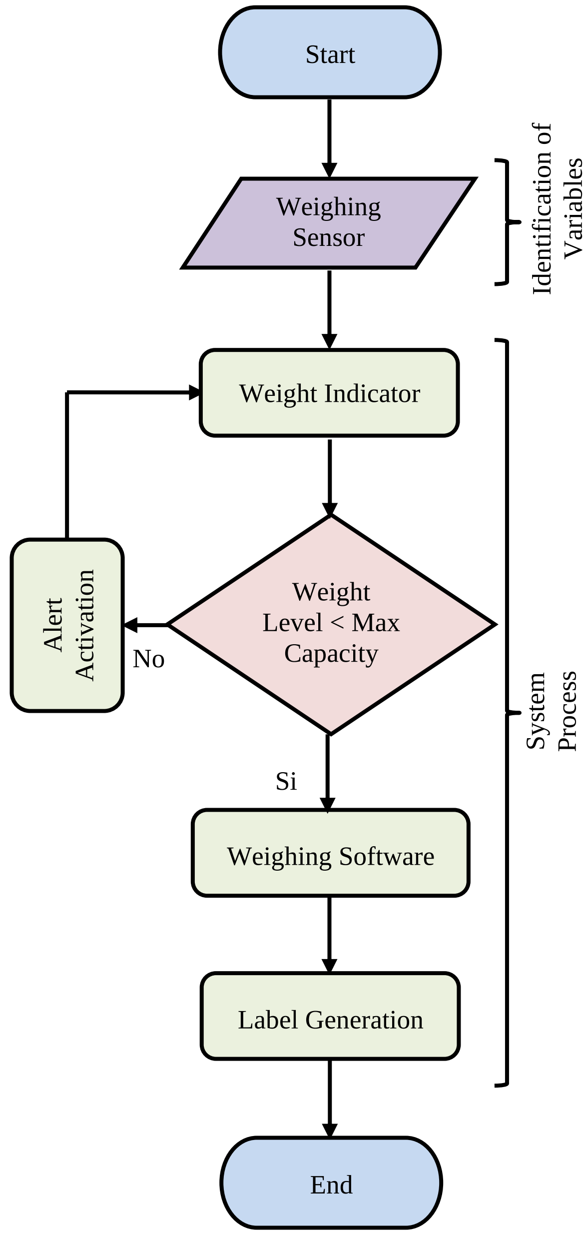

Fig. 1 Flow diagram of the encoder weighing system.

As shown in Fig. 1, the encoder weighing system consists of two main elements: Identification of the variable where the load sensor is located. The system process, where the weight indicator processes the data and sends it to the weighing software and the weight labeller. Each main element of the system is described as follows:

3.2.1. Identification of Variables

In this stage, the characteristics of the main devices that were selected for the encoder weighing system are described, such as the load cell, weight indicator, platforms and labeller.

Table 1. Requirement of the characteristics requested by the customer.

Equipment		Characteristic
Electronic balance	Capacity	50Kg x 10g
	Platform size	40 x 60 cm.
	Function	Tare and zero
	Communication	RS232
	Protection	IP 66
	Unit	Kg , Lb
	Operation mode	Manual and automatic
	Power supply	Rechargeable battery
Labeler	Communication	RS232 ,USB.
	Mode	Thermal Transfer
	External memory	Min. 2GB.
	Others	Control panel and display

For this, it is important to preview Table 1, which indicates the requirement requested by the client. After having visualized the client's requirements, next, we will talk about the system devices and the criteria that were evaluated to obtain the most appropriate selection.

Load Cell

It is a device that can obtain an electrical signal proportional to the applied force, which offers a variety of formats due to the many mechanical requirements of embedded systems [18].

In the implementation to guarantee the work, a KELI brand cell was used, model UDB-SS in which the following characters can be observed in Table 2.

Weight Indicator

It is an electronic system that, by processing an electrical signal in a load cell, converts it into a digital signal that can show the weight or the result obtained in real-time on a screen [19]. The same thing happens with the choice of the platform of 304 stainless steel model HD4560 -SS that has a dimension of 40 x 60 cm; in which this type of platform is widely used in the industry where a lot of humidity or corrosion is applied [20].

Currently, some various brands and models have Ip 66 protection, but an indicator of the HAND-FREE model 9001 brand was chosen since it has various characteristics named in Table 3.

Table 2. Characteristics of the UDB-SS load cell

Rated load	**60Kg**
Sensitivity	2.0 ± 0.2m V/V
Temperature range, operating	-10°C- + 50°C
Input resistance Output resistance	404 ± 15W 350 ± 3 W
Excitation is recommended. Excitation, max	10V DC 15V DC

Table 3. Characteristics of weight indicator TP9001

Direct power supply	220VAC
Rechargeable battery	6V 3.2A.
A/D conversion	1/40000, max. input 15 mV.
Supports	04 cells of 350 ohms. 08 cells of 700 ohms.
Weight units	Kg, Lb., g and oz.
RS232 interfaces	RS232.

Table 4. SBARCO T4 labelling machine

Print	Direct Thermal / Thermal Transfer
Memory	8MB SDRAM. 4MB Flash ROM. SD Expansion Slot, up to 4GB.
Communications	Serial, Parallel, USB master/slave, Ethernet
Environment operation	5°C ~45°C (40°F~104°F)
Control panel	4 multifunctional buttons with LED light

Labeling Machine

A SBARCO brand labelling machine, model T4. It is high-performance equipment with industrial capabilities. It has easy-to-operate software and hardware, is compact and small, but has a large storage capacity [21].

Table 4 shows the main characteristics of the labeller in more detail. Which it is a device that can be adapted to the client's needs since it has various means of communication and the availability of work with thermal transfer, which is essential for this research work.

3.2.2. System Process

After describing the main characteristics of the devices to be used, the system's operation will be briefly explained. As can be seen, Fig. 2 shows the physical components used in the system, which have been listed in alphanumeric order to understand the operation in detail. As a first point (a), we reference the product that will be weighed in the sausage plant, in which the majority are frozen products.

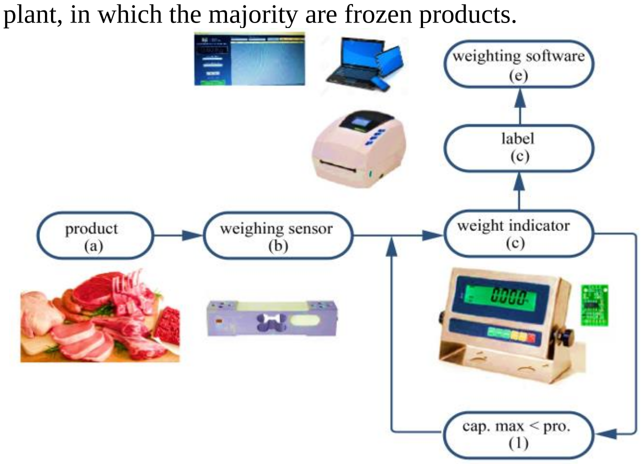

Fig. 2 System operation

Fig. 3 label Design

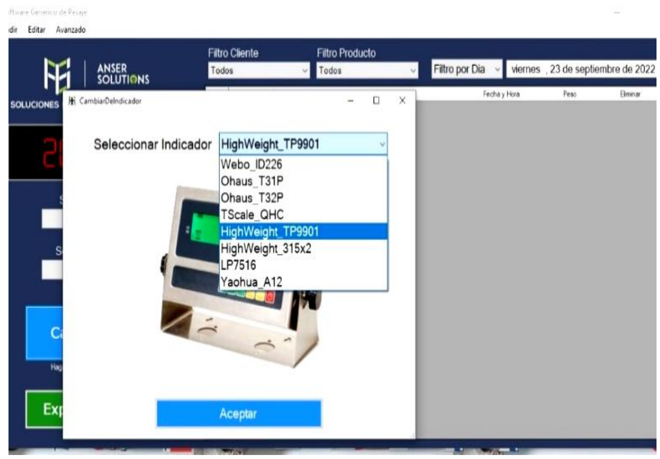

Fig. 4 Weighing System Software

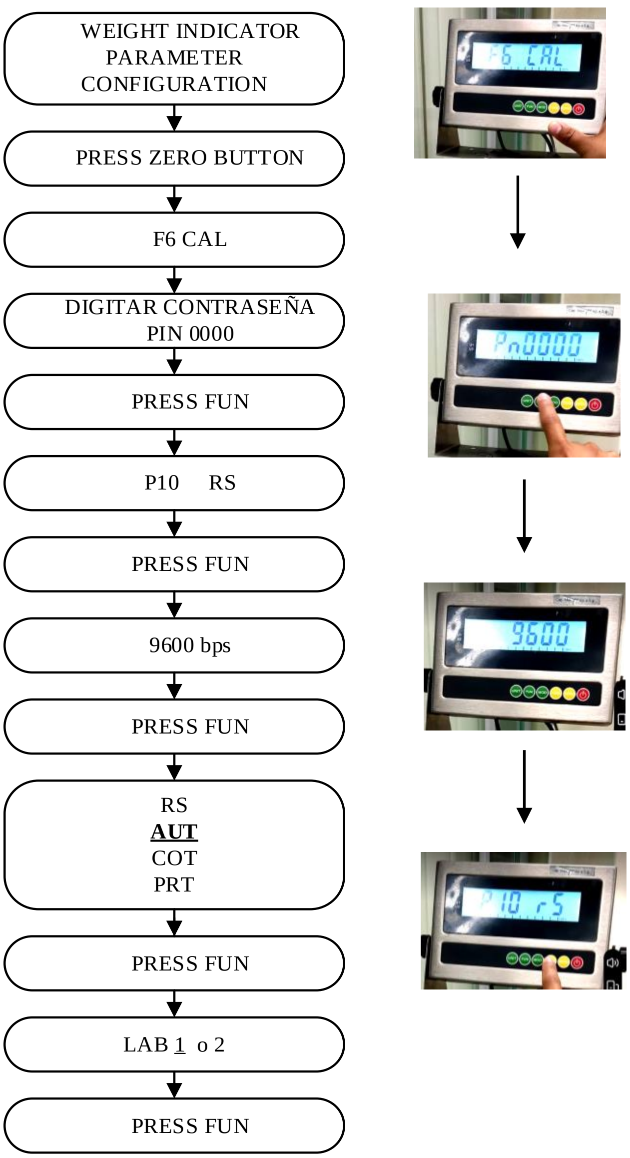

Fig. 5 weight indicator parameter settings

Then, the product will be weighed on the platform where the load cell (b) will be installed, which will be in charge of converting the applied force into an electrical signal that is captured by the weight indicator (c), which is a device that It will process the analog signal to digital so that it can be displayed on an LCD screen. Likewise, the weight indicator has an RS232 interface that will be installed directly to the SBARCO T4 (d) labeller, which will print the 60 label designs that were developed according to the client's requirement, where the product must be described, date of expiration, net weight, price per Kg, total payment and barcode, which can be seen in Fig. 3. It should be noted that the development of the design was done in the Bar Drawer software [22].

In the same way, by means of an RS232 to USB converter, the data will be sent to a computer, which will have software (e) shown in Fig 4, designed to capture the weight and work with the database to have the daily record for future inventories that intends to be applied to optimize the dispatch area, where the various deficiencies regarding the delivery and exit of products from the study area were visualized [23].

Finally, another important point to discuss is point (f), which indicates that this process will be activated when the product exceeds the maximum capacity of the electronic scale or load cell. If that happens, the indicator will automatically send an alert through a siren and will block the sending of data to the labeler and software. For this, the devices, such as the weight indicator and labeler, were previously configured to fulfil this function, which we can see in the following diagram of Fig. 5 and Fig.6.

Fig 5 shows the configuration of the indicator for automatic sending through the rs232 output to the labeler, in which the sending speed of 9600 bauds was configured. Likewise, the type of information to be sent in the said device was configured, and the programming of the minimum (200g) and high (50 kg) limits for the activation of the alarm was also carried out. These limit regulations are intended to guarantee the correct weighing of the products. It will also serve as an indicator when we are outside the limits allowed according to the minimum and maximum capacity.

On the other hand, in Fig. 6, the labeller's parameters are configured, indicating that the frame will be sent to line 7 with a maximum of 6 characters. Likewise, it was configured to operate by means of thermal transfer because polypropylene ribbon will be used to contrast the label better. Additionally, the keyboard functions and the activation of the 4GB external memory to store the label designs were also enabled. It is important to indicate that the internal memory of the labeller was not used since its capacity is limited to 60 designs.

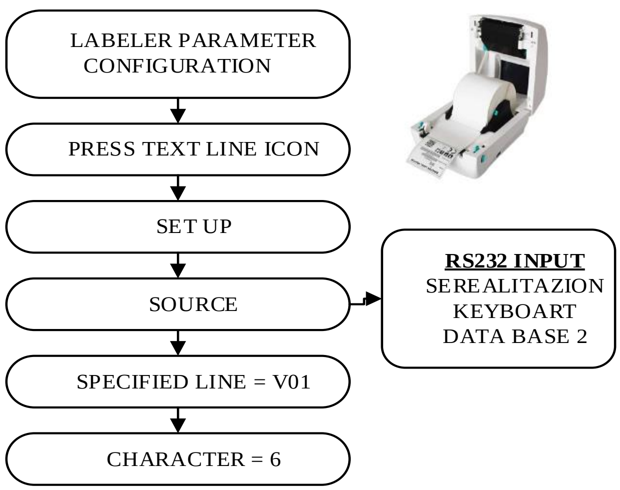

Fig 6. Labeller parameter configuration.

Fig. 7 System Installation

4. Results and Discussion

4.1. Results

At this stage, mention is made of the results obtained in the implementation process. In which the various installations of the encoder weighing system were made, shown in Fig.7.

After installation, the equipment was calibrated, for which the repeatability and eccentricity test shown in Tables 6 and 7 was performed. Likewise, before carrying out the tests, it was determined that the installed scale is class III because it obtained a scale number ≤ 10000, in which, to obtain that result, the maximum capacity (50 kg) was divided by the division (10g). Below, Table 5 shows the characteristic a class III balance must have [24, 25].

Table 5. Class III balance

Class	Verification step	Number of verification scalars	Minimum range
Medium (III)	5g ≤ e	500 – 10000 (n =Max /e)	20 e

Table 6. Repeatability test

Measurement (N. º)	Load L1	Load L2
	L1 =50 (Kg)	L2 =25(Kg)
1	50.00	25.00
2	50.01	25.00
3	50.00	25.01

Table 7. Eccentricity test

Measurement (No.)	Determination of E		Error determination corrected	
	Minimum load (Kg)	Kg	Carga (Kg)	Kg
1	0,10	0,10	15,000	15,00
2		0,10		15,01
3		0,10		15,00
4		0,10		15,00
5		0,10		15,00
weight code	ZT-10		065MM Y 066MM	

On the other hand, to perform the calibration tests shown in Tables 6 and 7, it is very important to find the minimum capacity shown in equation 1 and the minimum load in equation 2.

$$MC = VD * MR \quad (1)$$
$$MC = 0.01Kg * 20 = 0.2Kg\ (200g)$$

$$ML = VD * MR2 \quad (2)$$
$$ML = 0.01Kg * 10 = 0.1Kg\ (100g)$$

- MC = Minimum capacity.
- VD = Verification division (e)
- MR = Minimum range.
- MR2 = Minimum range/ 2.
- ML = Minimum load.

In the same way, after finding the capacity and minimum load, it is important to indicate that the calibration was carried out at a temperature of 22º C and humidity of 72.2%. In addition, standard weights identified with the code ZT-10 (100g), 065-MM (5Kg), 066-MM (10kg), 067-MM and 068MM (20Kg) were used.

Likewise, after the calibration, the system's operability was verified using the frozen products shown below.

2	5
1	
3	4

Fig. 8 Final process of the weighing system.

In Fig. 8, the final process is visualized. As the first point (A), the encoder weighing system is observed, in which the weight will be captured, and a label will be issued, as shown in Figure 3. Later, in the second point (B), the vacuum packer will be in charge of sealing the product. Then, in the third point (C), we proceed to store the product with its respective identifying label. Finally, in the fourth point (D), the weighing software is observed where I capture the product's weight, which will be stored in an Excel table for the daily inventory to be applied in the study area.

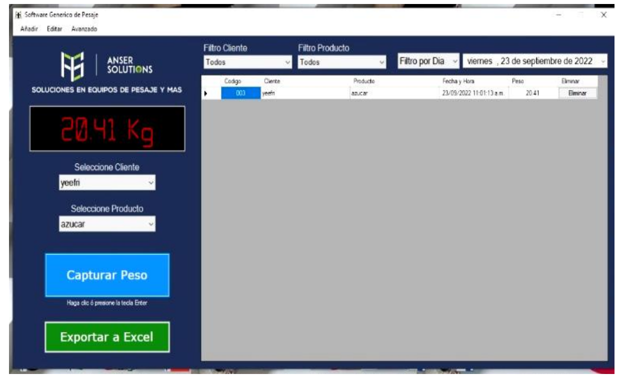

Fig. 9 Final software of the weighing system

In addition, after the weighing and labeling operation, the software that was developed to capture the weight of the product was reviewed, in which the final finish of the software is shown in Fig .9, which shows us the option to capture weighing and export the daily capture in an Excel table that is shown in Fig.10.

	A	B	C	D	E	F
1	Codigo	Cliente	Producto	Fecha y Hora	Peso (Kg)	
2	1	CERDYCAR	PANCETA	23/09/2022 11:01	2,91	
3	2	CERDYCAR	BONDIOLA	23/09/2022 11:01	3,11	
4	3	CERDYCAR	SOLOMILLO	23/09/2022 11:01	0,98	
5	4	STEINSEC	CHORIZO P.G	23/09/2022 11:02	0,65	
6	5	STEINSEC	PANCETA	23/09/2022 11:02	3,52	
7	6	STEINSEC	PIERNA	23/09/2022 11:02	12,02	
8	7	STEINSEC	PIERNA	24/09/2022 11:02	20,41	
9						

Fig. 10 A daily log of the weighing system

In Fig. 10, the export of the weighing software is observed, where a satisfactory result was obtained since the data that was intended to be obtained was correctly sent, such as the code, client, product, date and time, and weighing. Which, it will serve as a guide to carry out the inventory of entry and exit of the products of the packaging area where the project was implemented.

Fig. 11 Physical test of polypropylene label

Figure 11 shows the labelling of the labelling machine in the various products offered by the entity, in which polypropylene labels and tapes are used, demonstrating its high quality in the frozen products that we used at the time of the tests.

Table 8. Test of the encoder weighing system and the traditional system

Item	Traditional scales (Kg)	Proposed balance(Kg)	Absolut mistake	Relative error(%)
1	20.40	20.42	0.02	0.10
2	12.10	12.11	0.01	0.05
3	3.53	3.54	0.01	0.05
4	0.62	0.62	0	0
5	5.14	5.16	0.02	0.10
6	6.20	6.21	0.01	0.05
7	35.42	35.45	0.03	0.15
8	34.23	34.25	0.02	0.10
9	11.23	11.24	0.01	0.05
10	4.89	4.89	0	0
11	4.55	4.56	0.01	0.05
12	2.32	2.32	0	0
MAE (Mean Absolute Error)				0.058%

Finally, Table 8 shows the results obtained in the test carried out on the proposed weighing system and the traditional system, in which, as can be seen, an absolute error of +-0.03 and a mean absolute error of 0.058% were obtained. It should be noted that the proposed weighing system has a resolution of 0.01 kg (10g).

On the other hand, after the installation, a post-survey was carried out through the Google form to the 17 operators who work in the dispatch area, which consists of 4 questions that serve as support to verify the project's conformity.

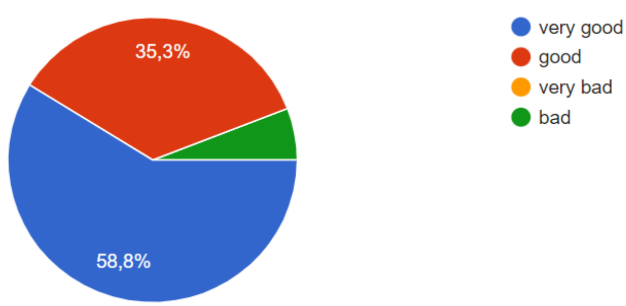

Fig. 12 How would you rate the new weighing system installed in the dispatch area?

Fig.12 indicates that 58.8% consider that the installed weighing system is very good, 35.3% good, and finally, 5.9% indicated that it is bad.

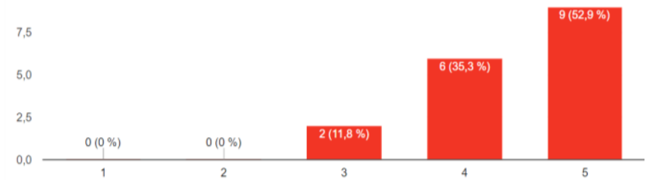

Fig. 13 How do you rate the system's weighing software?

In Fig. 13, the operators indicated on a scale from 1 to 5 that 52.9% consider that the installed weighing software deserves 5 points, 35.3% indicate 4 points and finally, 11.8% mention 3 points.

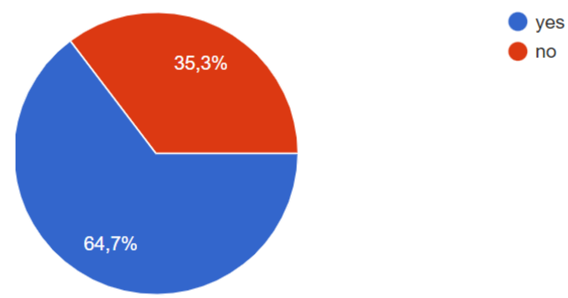

Fig. 14 Do you think that continuous training is necessary for the correct learning of the system?

In Fig. 14, 64.7% of the respondents indicate that they require continuous training for the correct system learning, and 35.3% consider that they do not.

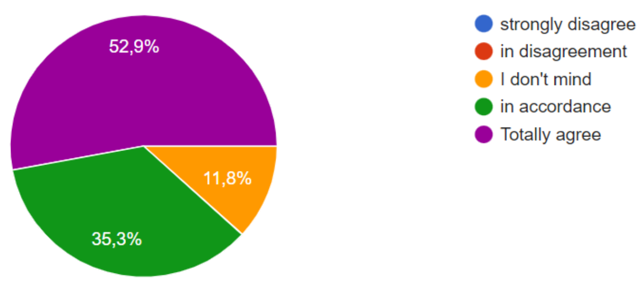

Fig. 15 Do you think that the system made improvements in the dispatch area?

Finally, in Fig. 15, 52.9% of the respondents fully agree that the system made improvements in the dispatch area, while 35.3% agree and 11.8% do not care. If there was an improvement

4.2. Discussion

As can be seen, implementing the encoder weighing system aims to optimize time, providing users with more efficient control of the products. For this, various devices were used that meet the purpose of the project, so in the first instance, an electronic scale model TP9001 was chosen, in which the great precession could be verified in the repeatability and eccentricity tests, obtaining an error of + -1d = 0.01Kg in the load L1 and L2. While the article [13] obtained an error of 0.1 Kg in the eccentricity tests. Additionally, the test done in Table 8 is added, where an absolute mean error of 0.058% was obtained, which exceeded the expectations of precision similar to the research work [11] and [12], where they obtained an MAE of 4% and 6%.

On the other hand, both articles [14] and [15] use systems such as RFID, PLC and POS for the registration of data from pigs and cattle, as indicated in the review of the literature, which I consider that although it is modern technology, it could serve as an alternative for the improvement of the project later on since in this article we intend the registration by means of a label that has a barcode generated by an SBARCO T4 labeller and direct communication towards software that stores the daily record in its database.

In the same way, it is important to indicate that although we are using devices with wired communication to link the indicator to the labelling machine and the indicator to the ordering system, this is due to the fact that the system is fixed in a certain area. However, there are other alternatives that can avoid wired communication and work with wireless devices such as Bluetooth and Wi-Fi, which are devices more exposed to interference but also reliable for communication as applied in article [16,17] in your system.

Finally, in the present project, we are using a class III static system, which gives us a great advantage in precision since it has less margin of error, unlike using a class III dynamic weighing system that depends on movement, in which it is usual to see it in a truck scale axis x-axis, as shown in article [16], which seek to give an improvement in the relative error.

5. Conclusion

In conclusion, the project implemented in the sausage processing plant gave positive results since it reduced the problems in the dispatch area, which generated a loss of time because they did not have a label to identify the product quickly; In addition, the devices with which they work were not adequate to have better control of the entry and exit of the products. For this reason, it was decided to provide a solution with an encoder weighing system, in which the most appropriate equipment was selected to satisfy the customer's requirement, shown in Table 1. Likewise, the user's compliance was demonstrated through a post-installation survey, shown in Fig. 12,13,14 and 15, where a large percentage approve that the encoder weighing system improved in the study area.

Likewise, this article demonstrates that the coding system meets the appropriate criteria to be installed in various sausage plants since it provides us with optimization and a simpler operation when registering the product through a labelling machine and weighing software, obtaining 98% efficiency in the repeatability and eccentricity tests, in which we guarantee correct operation. Although it is true that several similar systems on the market fulfil this function, this project differs from the rest because they are one of the most economical and simple to operate; In addition, it has software designed to be adaptable to any indicator brand and model.

On the other hand, it is important to indicate that the design is in the process of evaluation and testing for future projects in the industry since that system has the availability of coupling network modules, WIFI, and Bluetooth that will consume us to able to apply it together with IoT. (Internet of things) that today is revolutionizing the Peruvian industry.

Finally, it is recommended that when using the system, some observations should be considered, which are the following. As it is an electronic system, it is recommended to periodically calibrate the scale, as was done in Table VI and VII, in order to obtain a correct weight. In the same way, it is recommended to charge the scale for 8 to 10 hours as long as the weight indicator tells you to charge. This is done as a preventive measure for later breakdowns. On the other hand, with respect to the SBARCO T4 labeller, it is recommended to only definitively use 4GB memory since if a higher memory is used, the device will not read. Finally, suppose you want to use the labelling machine for frozen products. In that case, it is important to use polypropylene tape and the same quality label since this will give it more resistance to humidity and rapid deterioration due to the environment where it is stored.

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