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Effect of weight variation in milk bags in aseptic packaging caused by Festo servo-assisted sealing

Incidencia de la variación de peso en bolsas de leche en envasadoras asépticas ocasionado por sellado servoasistido Festo

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Abstract: The objective of this study was to determine the cause of weight variation of up to 60g in milk bags in an aseptic packaging machine, variables directly related to the weight of the bags were analyzed, leading to the determination that the cause was the horizontal sealing with Festo servo motors, the actuation and synchronization generated by the communication between the PLC and the servo motor controller were identified as the culprit, this system was homologated due to worldwide disruptions in the acquisition of technological equipment, as a result of identifying and correcting the system, a weight variation of +/-3g was achieved in the packaging, which aligns with quality standards, this improvement was attributed to the optimization of routine execution times and data packet transmission times.

Keywords: horizontal sealing, variation, weight, servo motor, packaging machine

Resumen: El objetivo de este trabajo fue determinar el causante de variación de peso de hasta 60g en bolsas de leche en una envasadora aséptica, en el que se analizaron variables que están directamente relacionadas con el peso de las bolsas, en ella se llega a la determinación que el causante es el sellado horizontal con servomotores Festo, el accionamiento y sincronía generada por la comunicación entre PLC y el controlador del servomotor, ya que este sistema fue homologado dado a las afectaciones de orden mundial para la adquisición de equipos tecnológicos; como resultado del hallazgo y corrección del sistema se llegó a obtener una variación de +/-3g en el envasado lo que acorde a los estándares de calidad, los cuales se debió a tiempos de ejecución de rutinas y tiempos de envío de paquetes de datos.

Palabras clave: Sellado horizontal, variación, peso, servomotor, envasadora.

1. INTRODUCTION

During the 1940s, there was a need to extend the shelf life of milk. Various storage methods were employed, including cans and polyethylene boxes. The properties of packaging materials were analyzed, and treatments for milk were explored, along with methods for sealing containers [1]. Recognizing the necessity of facilitating packaging, mechanical systems were developed using pulleys, gears, pinions, motors, and manual operation. Over the years, with the advent of technology, packaging systems have been improved to enhance maintenance, autonomy [2], and to avoid production downtime caused by malfunctions or critical part damages, which result in financial losses and customer dissatisfaction [3]. Technology and optimization play a crucial role in integrating higher-performing, more efficient, and controllable equipment into production systems. Transitioning from motor systems with gear sets to systems incorporating programmable logic controllers (PLCs) and servo motors allows for greater efficiency, control, and precision in repetitive movements [4]. Furthermore, it enables control over various parameters such as movement type, speed, and acceleration ramp, determining required positions based on operation needs, thus enhancing process quality [5].

The implementation of automation in processes has elevated production and product quality to high standards, allowing companies to excel in the market. Investing in cutting-edge technological systems reduces time, costs, resources, and increases profits [6]. For manufacturers, employing fully functional automated equipment that meets their needs is a significant challenge.

This project presents a solution to a problem arising from complications in acquiring electronic components due to global phenomena, which directly impacts the production of dairy products. Delays in the delivery of technological products for industrial automation necessitate equipment homologation for application implementation. This is particularly evident in the dairy industry, where packaging systems are affected. The manufacture of new machines requires elements from different brands to fulfill control functions. Homologation not only affects mechanical and electrical characteristics but also integration with other control systems. This work analyzes the impact of integrating Festo servo motor controllers into horizontal jaws for sealing polyethylene bags in an aseptic filler, exploring how it may affect variations in the weights of bags containing dairy products. Identifying the cause enables evaluation of variables to be modified [7], whether they pertain to systems, mechanical parts, electrical components, programming, or actuation adjustments. This is essential for aligning the system with the country's [8] food technical standards, as product quality is regulated by the quantity provided to consumers.

2. METHODOLOGY

The present research project is a case study applied to UHT milk aseptic fillers with servo-assisted sealing. It follows a methodology based on 6 fundamental steps to analyze the behavior of implementing Festo servo motors in horizontal seals and the impact of their operation on weight variation. The goal is to arrive at a tangible solution with significant impact. These steps consist of:

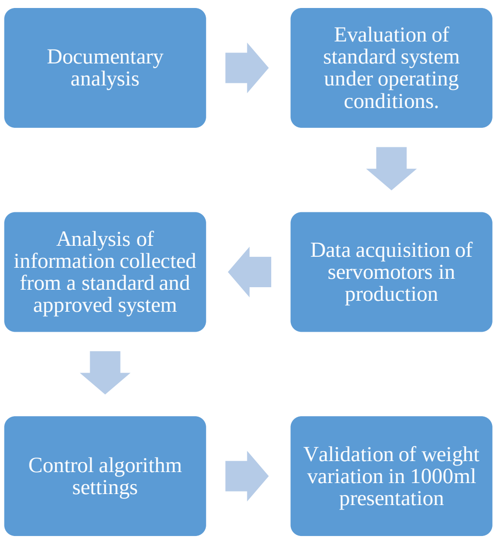

Fig. 1 Development Methodology
Source: *own elaboration.*

- Documentary analysis: Gathering technical information about the new components incorporated and standardized into the system that may be affecting the variation.

- Evaluation of the standard system under operating conditions: In this step, the aim is to identify systems that may directly affect the variations.

- Acquisition of servo motor data in production: As it is a standardized system, obtaining information on the behavior of this component in the system aims to establish if it is one of the aspects directly related to the variation.

- Analysis of collected information from the standard and standardized system: This item builds on the information gathered from the evaluation and data acquisition, identifying aspects that are affecting and need to be addressed in the correction.

- Adjustment of the control algorithm: As the filler is an automated system, adjustments, both in programming and mechanical settings, are crucial steps in the research methodology to achieve tangible results.

- Validation of weight variation in 1000ml presentation: In this step, conclusions from the research can be drawn, with the entire methodology reflected in the adjustment and obtaining of a variation consistent with what is offered to customers.

3. ECONOMIC IMPACT

Considering that there are 10.000 liters of raw milk in the silo, of which around 2,000 liters would be lost due to pushing process losses and pipeline losses, the equivalent of 654 USD of packaged product would be lost due to the variation and the units that would not be packed if the variation is kept in line with what is offered.

Table 1: *Daily Cost Analysis*

Period		Daily	
Raw milk(kl)		10	
Estimated number of bags packaged		7.843	
Number of bags packed		+60g	-60g
		7.407	8.333
Number of unpacked bag		+60g	-60g
		436	490
Total product price packaged $USD	Without variation	11.764,71	
	With variation	+60g	-60g
		11.111,11	12.500,00
Price difference for unpackaged product for variation $USD		+60g	-60g
		653,59	735,29

Source: *own elaboration.*

If a projection is made for the week, it would be talking about a production of 60,000 liters, with a 5-hour packaging day, there would be an average loss of 5,330.88 USD. In Colombian pesos, this would be 22,389,705.88 pesos, which represents a significant loss for production.

Table 2: *Weekly Cost Analysis*

Period		Weekly	
Raw milk(kl)		60	
Estimated number of bags packaged		56.863	
Number of bags packed		+60g	-60g
		53.704	60.417
Number of unpacked bag		+60g	-60g
		3.159	3.554
Total product price packaged $USD	Without variation	85.294,12	
	With variation	+60g	-60g
		80.555,56	90.625,00
Price difference for unpackaged product for variation $USD		+60g	-60g
		4.738,56	5.330,88

Source: *own elaboration.*

If we project over a period of 1 month, where 240.000 liters of raw milk would be packaged, maintaining stable production would yield a revenue of 350.000 USD, or 1.470.000,000 Colombian pesos. However, if production is maintained with a weight variation of 60g, there would be a loss of 21.875 USD, approximately 91.875.000 COP on average.

Table 3: *Daily, Weekly, and Monthly Comparative Analysis*

Presentation: 1000ml		Weight quallity 1020g		Variation: +/- 60g		Selling price: $1,5	
Period		Daily		Weekly		Monthly	
Raw milk(kl)		10		60		240	
Estimated number of bags packaged		7.843		56.863		233.333	
Number of bags packed		+60g	-60g	+60g	-60g	+60g	-60g
		7.407	8.333	53.704	60.417	220.370	247.971
Number of unpacked bag		+60g	-60g	+60g	-60g	+60g	-60g
		436	490	3.159	3.554	12.963	14.583
Total product price packaged $USD	Without variation	11.764,71		85.294,12		350.000,00	
	With variation	+60g	-60g	+60g	-60g	+60g	-60g
		11.111,11	12.500,00	80.555,56	90.625,00	330.555,56	371.875,00
Price difference for unpackaged product for variation $USD		+60g	-60g	+60g	-60g	+60g	-60g
		653,59	735,29	4.738,56	5.330,88	19.444,44	21.875,00

Source: *own elaboration.*

This would be a proposal for a 5-hour production/6-day schedule. As the product demand increases, the producer will increase their operational capacity to a 24/6 schedule, with 5 hours allocated for CIP (Cleaning in Place) and sterilization processes to clean the machine. This would result in greater loss for the producer, as it would be reflected in the number of units and potentially lead to loss of customers. In this scenario, the producer engages in

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contract manufacturing, which could result in the loss of contracts.

Table 4: *Annual Cost Analysis*

Period		Annual	
Raw milk(kl)		2.880	
Estimated number of bags packaged		2.821.569	
Number of bags packed		**+60g**	**-60g**
		2.664.815	2.997.917
Number of unpacked bag		**+60g**	**-60g**
		156.754	176.348
Total product price packaged $USD	Without variation	4.232.352,94	
	With variation	**+60g**	**-60g**
		3.997.222,22	4.496.875,00
Price difference for unpackaged product for variation $USD		**+60g**	**-60g**
		235.130,72	264.522,06

Source: *own elaboration.*

If analyzed annually, it would mean 156,754 units are not being packaged due to overdosing 60g in the bags. Observing the table, it would result in a loss of $235.130,72 compared to the value of a production without variation beyond the standard. If considering the scenario of under-dosing the bags, there would be a larger number representing a higher income compared to the total packaged product without variation. In other words, an additional $264.522,06 would be billed for this difference. However, this cost would have a negative impact on the market, as it would not comply with product regulations and quality standards. This would imply that the brand could be penalized by regulatory authorities and may not be well received by the consuming public.

4. RESULTS

To determine which system was affecting the operation and weight of the packaging, the following hypotheses were considered as possible causes:

- Disturbance by the UHT.
- Tank balance level.
- Misalignment of the balance tank level sensor.
- Dispensing tube.
- Development system.
- Horizontal sealing system.

4.1. Disturbance caused by the UHT sterilizer.

The following exercise was carried out to rule out any effect of the sterilizer pressure on the balance tank that could be related to the variation:

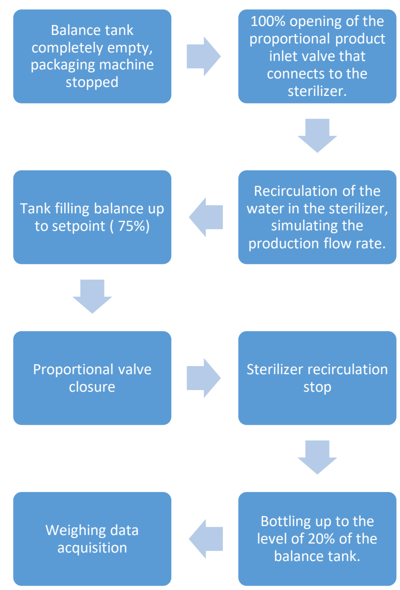

Fig. 2. *Procedure used for analyzing possible UHT disturbances*
Source: own elaboration.

From this exercise, the same results were obtained regarding the weight in the bag, with the same variation of +/-60g, ruling out any effect originating from the sterilizer.

4.2. Balance tank level and sensor misalignment

After ruling out issues with the UHT sterilizer, the balance tank level was analyzed. The operation of the product valve, which allows the product to pass from the process line to the filler, was reviewed. Subsequently, the proportional valve with its PID control was inspected. Its function is to ensure the level in the balance tank is appropriate, given the previous operation where the level is maintained at 75%. The regulation of the valve was ruled out; therefore, the calibration of the VEGA level sensor was performed. This sensor is a radar sensor that determines the level through the microwaves emitted and reflected by the product. It is directly related to the flow control valve controller.

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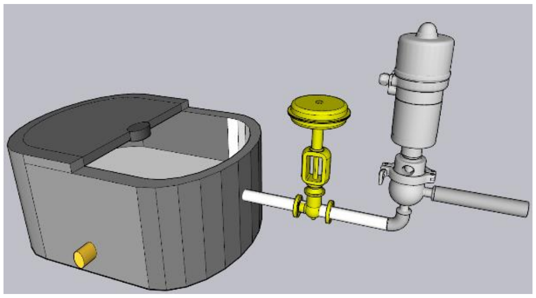

Fig. 3. *Balance tank, proportional valve, product valve*
Source: *own elaboration.*

The tank was filled to 50% of its capacity, and the relevant parameters were configured to estimate the level with the sensor. Once this value was obtained on the sensor, a filling test was conducted using the same water as in the previous test, resulting in the same weight variation. Therefore, sensor and level issues were ruled out.

4.3. Dosing tube

The next downstream system to review is the dosing system composed of a servo motor, membrane T valve, dosing tube, centering rod, and closure. The impact on weight with this system due to the variation is significant since it is the system that doses the appropriate amount into the bags. The following points were reviewed in the dosing system:

- Opening of the dosing tube
- Servo motor calibration
- Centering of the internal rod of the dosing tube

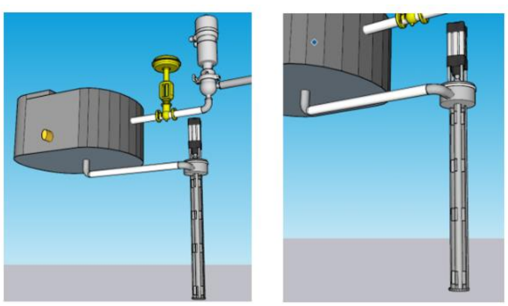

Fig. 4. *Dosage system*
Source: *own elaboration.*

The structure of the system can be observed (Fig. 4), in which the direction of the product starts in the balance tank, enters the membrane valve, and descends through the inner tube of the dosing tube, completely filling it with milk. Depending on the opening generated by the servo motor, the internal rod moves downwards or upwards accordingly. This way, the product flows out and fills the bags. Based on this, the opening factor of the tube is checked, including both the complete closure and the millimeters of opening. This is done with proper homing and calibration of the servo motor using the internal rod. The value entered for the opening is verified with a vernier caliper, and indeed, the values corresponded.

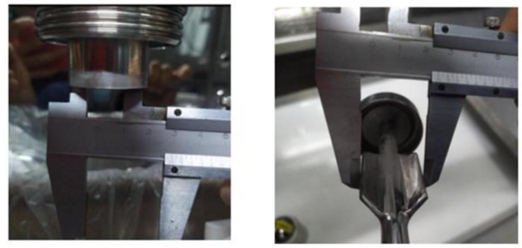

Fig. 5. *Measurement of rod and internal tube of the dispenser*
Source: own elaboration.

The tolerance of the centering of the internal rod of the dosing tube was another aspect that could affect it, as when the product fell, the blades of this rod could internally vary the opening, with a difference of 5mm, which did not significantly affect the weight.

After properly reviewing and making the necessary adjustments, bag filling tests were conducted, and the same variation data continued to be observed. The system is ruled out.

4.4. Development System

The issue of plastic development drag involves the "taca" sensor for bag detection, the rubber wheels, and the operation of the motor speed controller of the development system (Fig. 6).

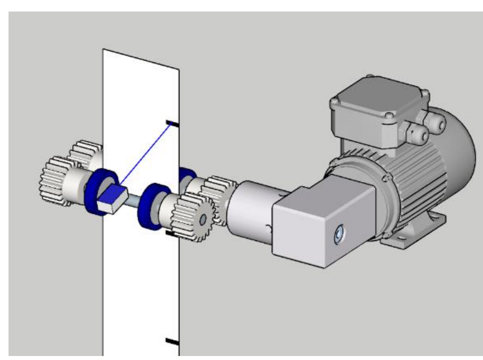

Fig. 6. *Packaging development system*
Source: own elaboration.

When using a photoelectric sensor, they become misaligned due to incidence and reflection on the polyethylene used, resulting in false readings of the "taca," whether in white detection or black detection (depending on how the sensor is configured). This detection affects the reducer motor of the development system by sending a stop signal to the controller. According to the selected stop mode option in parameter P045 of the Powerflex 525 drive used for this purpose, the DC brake is employed [9].

4.5. Horizontal Sealing System

The horizontal sealing system used in the servo-assisted packaging machine (Fig. 7) involves a motion transfer mechanism, where the servomotor converts circular motion into linear motion through a connecting rod. This allows for the opening and closing of the horizontal sealing jaws. Subsequently, using electric resistances, the transverse sealing of the bags, already filled with product, is carried out. This sealing process involves two steps: one for sealing the upper part of the preceding bag and another for sealing the lower part of the subsequent bag.

To analyze the weight impact in relation to the effect generated by the Festo servomotor, graphs of the equipment's behavior were generated using the Festo Automation Suite tool. Information was collected according to the set parameters, which include position, velocity, and acceleration, as detailed below:

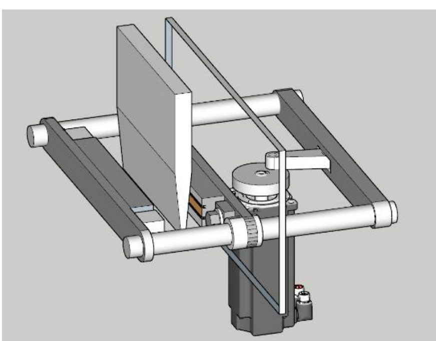

Fig. 7. *Servo-assisted horizontal sealing system*
Source: own elaboration.

You can see the encoder reading of the servomotor (Fig. 8), which indicates its position. During the execution of movements, it can be observed that it is consistent with the setpoint established in the control routine. It is noticeable that it has a period of 1500ms with a symmetrical behavior.

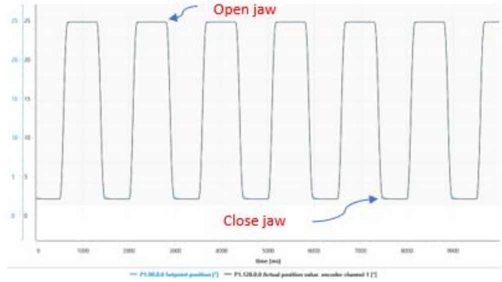

Fig. 8. *Comparison of current position vs. setpoint of the servomotor*
Source: *own elaboration.*

If we include motor operation parameters, such as speed, in the analysis, a similar behavior can be observed. The control exerted by the controller over the servomotor allows for an approximate value of 266°/s between the actual speed value and the setpoint (Fig. 9).

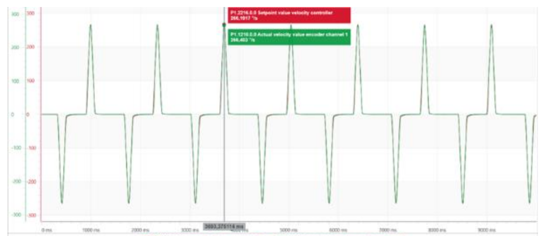

Fig. 9. *Servomotor speed, actual vs setpoint*
Source: *own elaboration*
.

The behavior of the servomotor speed curve can be detailed (Fig. 10), where approximately in 100ms, its speed transitions from 0°/s to 266°/s before descending back to 0°/s 100ms later. This means it takes approximately 200ms for the servomotor to transition from closed (0°) to open (25°), with the maximum speed established at 48% of the jaw's travel.

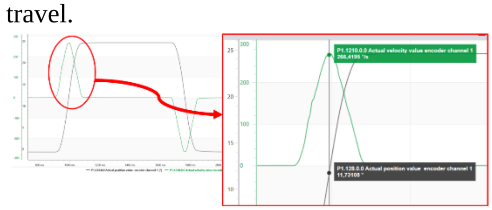

Fig. 10. *Behavior of speed relative to position*
Source: *own elaboration.*

Similarly, the comparison between the actual and ideal values of the acceleration that the servomotor should have with respect to the assigned parameters can be appreciated (Fig. 11). It can be observed that the acceleration for closing is different from that for opening, according to the operation, which is understood just as the speed at which the servomotor wants to reach its final position.

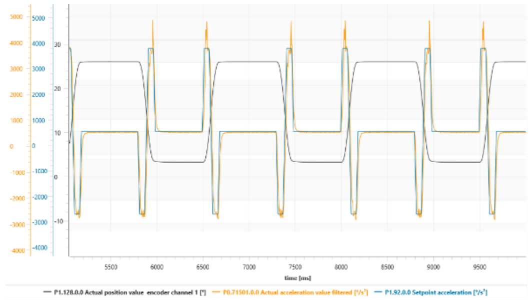

Fig. 11. *Acceleration of the servomotor, real vs setpoint*
Source: own elaboration.

Not finding conclusive evidence that there is any significant difference affecting the variation from the standpoint of control parameters, the behavior of the servo regarding its physical and electrical characteristics must be analyzed.

In the position vs. current graph (Fig. 12), the motor current behavior when changing position can be observed. A symmetrical behavior is detailed in each period of the pulses generated when transitioning from the 0° position (closed) to 25° (open). A current peak of 2A is observed lower when transitioning from open to closed since it is in its resting state where no effort is generated, and an additional 2A is needed to transition from closed to open as it needs to reach its maximum opening and maximum effort with the motor load. However, these values are in line with the peak current that the servo motor can withstand.

Although there is evidence of overconsumption when the clamp is closed according to Annex 2 (peak current 18.5A) [10], and this is precisely due to the contact position between the two parts of the clamp, it does not represent an affectation to the weight. Additionally, the times of each state can be appreciated, 500ms for closed and 700ms for open. It could be understood that the 200ms difference corresponds to the execution cycle of the clamp routine, in which new plastic must be displaced for filling.

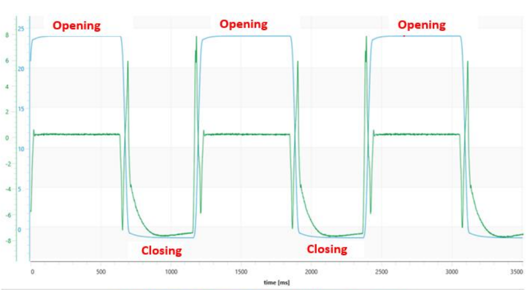

Fig. 12. *Position vs current of servomotor CMMT*
Source: own elaboration.

Discarding the aforementioned characteristics for variance analysis, only the compatibility in response between the PLC and the controller for bag weight variation and the servo motor's response behavior concerning communication and routine times remains.

To better understand the operation of all integrated parts in the system and how it may affect weight variation, it is important to consider the sequence of operations to be performed during packaging. The execution of each element's actuation according to the programming is based on a sequential structure, where the end of each stage is the beginning of the next, in an automatic operation.

Communication between the PLC and Festo Driver must be in accordance with data transmission and reception times, as all electronic devices operate in cycles according to their capacity. Hence, this aspect is analyzed as a final measure to determine if the standardization is suitable for this application. Based on the gathered information to add the add-on Instruction, it should be noted that it must be in a continuous task executed cyclically [11], even though packaging is programmed in periodic task segments whose execution is determined by a time interval, with shorter intervals having higher priority in execution [12].

Initially considering communication times, the weight behavior concerning different routine cycle times is analyzed. According to the cycle time in the routines of the machine's standard program, the control signal execution routine is parameterized as a periodic routine to avoid consuming too much PLC memory. Despite Festo's recommendation that the execution routine should be continuous, the filler performs multiple routines in parallel, requiring more controller resources to carry out all tasks. Based on this, the weight variation behavior concerning routine cycle adjustments is analyzed.

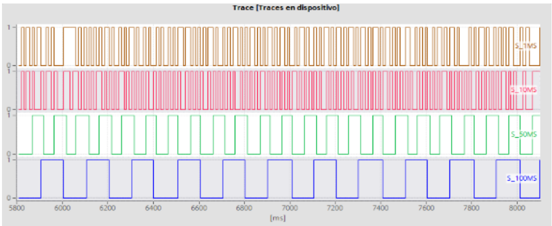

Fig. 13. *Simulation diagram of routine times at different intervals*
Source: *own elaboration.*

Starting from the timing diagram (Fig. 13), we can gain insight into the frequencies at which the jaw

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operation routine would be executed, along with the values of the servo motor control parameters, assuming a routine cycle time of 100ms.

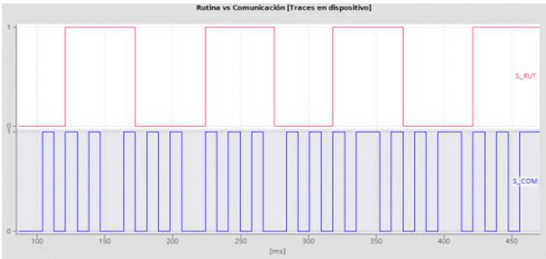

Fig. 14. *Routine frequency of 100ms vs RPI of 20ms*
Source: *own elaboration.*

The cycle time of the jaw routine execution can be analyzed (Fig. 15), where 5 data transmission cycles are achieved per communication between the PLC and the servo motor controller. The data packet interval is set at 20ms, meaning the same parameter data would be sent during the entire 100ms duration of the routine.

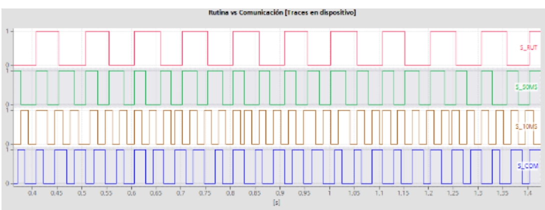

Fig. 15. *Comparison of routine times vs RPI time*
Source: *own elaboration.*

Comparing the cycle times of the routine and the pulse train of the requested packet interval (Fig. 15), where the data update would be reflected as follows: Routine Signal (S_RUT) at 100 ms, Signal at 50 ms (S_50ms), Routine at 10 ms (S_10ms), and Communication (S_COM) at 20 ms. From the behavior of the graph, it can be seen that a routine execution period allows for data updating in the controller, thereby obtaining 2 values, whether equal or different, for the parameters during 1 transmission cycle.

Based on the behavior of the working cycles of each part, the weight behavior of the milk bags concerning these times should be analyzed. Weight data was obtained for the 900ml presentation, showing the following behavior.

Initially, tests were conducted with a few units to observe the variation behavior in the bags. The results of this improvement can be observed (Fig. 20), indicating a significant change as there is evidence of correlation between the weights. This filler is a 2/3 (2 enabled heads out of 3) with the last two heads enabled, designated as B and C. Its cycling operation is at 50 strokes per minute, meaning this number of strokes represents the number of bags per minute. A 10ms RPI and 10ms control routine are employed, showing values with little variation within the offered range.

HEAD	C	C	B	C	B	B
HIT/min	50	45	45	50	50	45
RPI (ms)	10	10	10	10	10	10
ROUTINE (ms)	10	10	10	10	10	10
# BAG	WEIGHT (gr)	WEIGHT (gr)	WEIGHT (gr)	WEIGHT (gr)	WEIGHT (gr)	WEIGHT (gr)
1	965	1060	1040	945	990	1050
2	965	1065	1040	945	995	1055
3	965	1060	1040	950	990	1050
4	965	1060	1040	950	990	1050
5	965	1060	1350	945	995	1050
6	965	1060	1040	945	995	1055
7	965	1060	1040	950	1000	1055
8	965	1065	1035	950	995	1050
9	965	1060	1040	950	995	1055
10	965	1060	1040	945	995	1050
Average (gr)	965	1061	1070,5	947,5	994	1052
Variance +/- (gr)	0	2,5	2,5	2,5	5	2,5

Fig. 16. *Behavior of variation initial test adjustments*
Source: own elaboration.

Although these data were obtained with water in an intermittent operation, meaning only that number of quantities were taken per test, and not in a continuous operation and under stable machine conditions (cabin temperature, peroxide temperature, UHT flow rates), the data point towards the assertive solution.

Now, in normal operation, continuous production, with product received from the sterilizer and under production conditions, the following samples are taken:

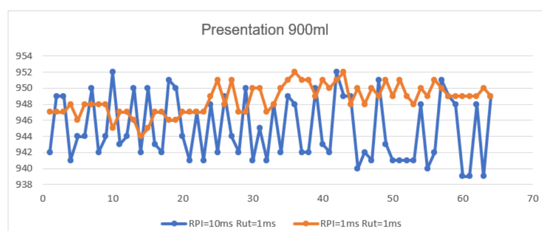

Fig. 17. *Response of weight variation at 10ms vs 1ms on RPI*
Source: own elaboration.

It can be observed that for the requested packet interval of 10ms and a routine cycle of 1ms (Fig. 17), the collected data are more dispersed, with weighing ranges oscillating between 952g and 939g, resulting in a variation of +/-6.5g. By modifying the communication times between the PLC and the servo motor driver to 1ms, the dispersion becomes smaller. The data behavior shows that heavier bags tend to have values closer to each other, with a maximum of 952g and a minimum of 944g, an average of 948g, and a variation of +/-4g, which allows them to fall within the product quality range.

The same configuration verification was carried out on the second head, where the difference between consecutive bags (Fig. 18) was observed, showing greater dispersion with a variation of +/-6.5g, which is significantly noticeable compared to the graph obtained from weighing the bags packed with an RPI of 1ms in sync with the jaw actuation control routine. In this case, the dispersion is minimal, the values are close to each other, and the variation is reduced to a difference of +/-5g, with maximum values of 938g and minimums of 928g, resulting in an average filling weight of 934.12g for a dosing aperture of 380mm.

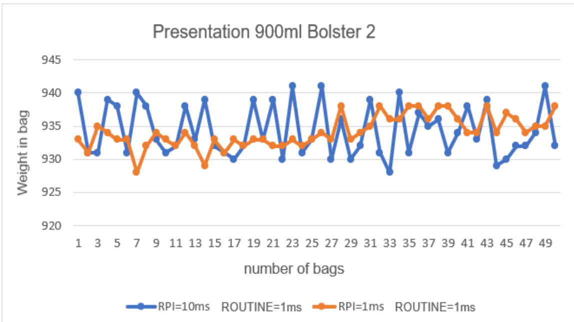

Fig. 18. *The response of weight variation at 10ms vs 1ms on RPI, Head #2*
Source*: own elaboration.*

A sample of 50 units (Fig. 19) was observed to analyze the weight behavior with routine timing adjustments and RPI. An average weight of 1040g was recorded for the packaging. From this, it was determined that the weight variation in production is within +/- 3g per bag compared to the value provided by quality control.

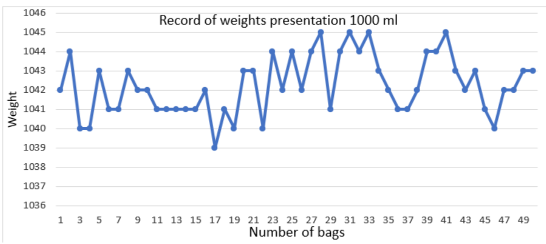

Fig. 19. *Comportamiento de peso con ajuste en rutina y RPI, cliente #1*
Source: *own elaboration.*

A second weight measurement was taken in the milk packaging production for the 1000ml presentation, equivalent to 1000g (Fig. 20), based on the density of the milk, estimated at approximately 1g/ml. From this sample of 50 units, it can be analyzed that there is an average value of 1040g and a variation range of +/-3g, ensuring the satisfactory quality performance of the filler.

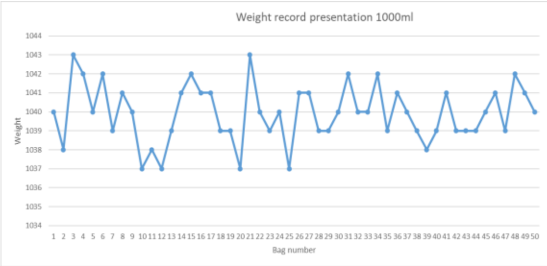

Fig. 20. *Production weight record, 1000ml presentation*
Source: *own elaboration.*

Following this, random monitoring is conducted on the line where the quality personnel verify both the weight and the sealing quality of the bags. An adjustment is made to the weight, maintaining an average value of 1025ml (Fig. 21).

Fig. 21. *Measurement of weight of freshly packaged milk bag"*
Source: own elaboration.

4.6. Validation of Client #2 Configuration

The same servo-assisted horizontal sealing system with Festo servo motors was employed for a second client who purchased a 4-head filler for packaging various presentations ranging from 400ml to 1200ml and different products (whole milk, lactose-free, skimmed). Therefore, it was necessary to ensure the same maximum variation of +/-5g difference in the product-filled bags. Hence, the same routine configurations and RPI (Request Packet Interval) used with client #2 were employed, resulting in the following samples:

The client simultaneously utilizes different presentations in the heads, enabling the packaging of the same product in various packages according to the production order for the corresponding presentation.

For head 1, a production order for packaging in a 900ml presentation was made, from which a sample of 50 units was taken to verify the weight of the bags. According to the data collection (Fig. 22), it can be observed that for a dosing aperture of 348mm, there is an average weight of 929g, corresponding to 929ml of packaged product, with a variation behavior of +/-3g, in line with the stipulated range. Ensuring accuracy in packaging 900g and not overfilling beyond the presentation value aligns more with quality and operational parameters.

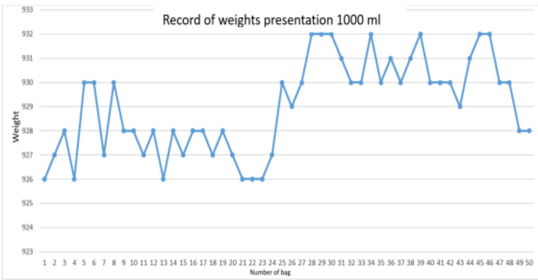

Fig. 22. *Weight of 900ml presentation of lactose-free milk, head 1*
Source: *own elaboration.*

Data sampling was conducted for head 2 (Fig. 23), which produces a 900ml presentation. One hundred data points were collected for analysis, revealing that this head exhibits more uniform behavior concerning its weights. Its mean value is 938g, and the values are closer to this figure with a deviation of 1.2. Although its dosing value is somewhat higher compared to the first head, this is purely due to operational differences in dosing values. The recorded data indicate a variation of +/-3g.

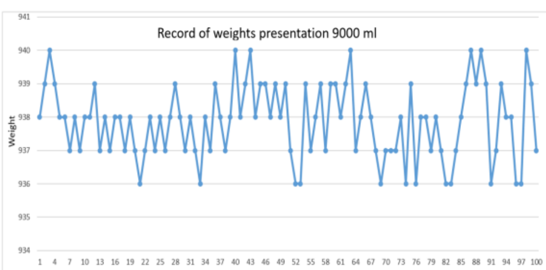

Fig. 23. *Production in 900ml presentation of lactose-free milk, head 2*
Source: own elaboration.

From the production of 1100ml in head 3 of the packaging machine (Fig. 24), with a dosing aperture of 369mm, it was observed that the variation range was +/-3, with the weight values deviating by 1.9g from the sample's mean value of 1138g.

Fig. 24. *Weight of 1100ml presentation, head 3*
Source: *own elaboration.*

For the 400ml presentation used in head 4, the weight values are relatively close together with a deviation of 1.2g from the sample's mean value, which was 416g. This variation represents +/-2.5g from the sample (Fig. 25), with a dosing aperture of 220mm.

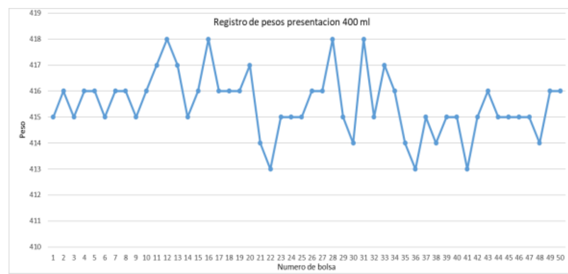

Fig. 25. *Weight records of head 4, 400ml presentation*
Source: *own elaboration.*

5. CONCLUSIONS

• The events of global nature directly impact any industry, starting with raw material extractors, passing through the production chains of each part of a product, and in turn those who use them to integrate them into final products, for which alternatives must be available to meet the needs in the ever-increasing technological world.

• Any change in elements within an automated system can have a significant impact on the process if it lacks extensive technical information, as homogenization can be supplemented with mechanical and physical characteristics, often without considering time for data analysis in processing.

• Product quality standards are crucial, especially in the dairy industry. Therefore, the implementation of machines that guarantee compliance with these standards makes companies competitive and stand out even more, ensuring consumers feel confident about the quantity and quality of the products they are purchasing. Hence, manufacturing machines with state-of-the-art technology to maintain quality and increase profits rather than generating costs and losses allows for the advancement of the dairy manufacturing industry.

• The impact of even a 60g variation in milk within a bag is significant when analyzed in batches. Moving from a difference of $0.09 per bag to $240.000 annually in production generates losses for a company investing in state-of-the-art equipment, which should be generating more profits instead of losses and expenses.

• Integrating more than one piece of equipment within a production system generates multiple potential factors in which a product may not fully meet a standard. In the polyethylene bag milk packaging production line, as discussed in this work, many factors such as pressure, level, valve opening, rod, plastic movement by motor, position sensor, and mechanical effector of a system can be involved in a single problem.

• Interpreting the datasheet and further investigating technical information about Festo servo motors allowed for a deeper analysis in terms of data transmission and reception in electronic systems, where aspects such as sampling frequency, routine execution times, and required packet intervals were not considered in a servo-assisted packaging machine with Rockwell servo motor integration. This allowed for a solution for both the manufacturer and the customer since it was the first integration with Festo servo motors, and it was not initially considered that this was causing such a significant variation in the weight of the milk bags.

• The timing diagram provided a broader view regarding the frequency of transmission pulses, where lower frequencies delay control data updates. Higher transmission frequencies provide updated data according to routine execution, even though these times may seem small at first glance and could go unnoticed, they led to a significant impact on production and system tuning.

• In this case, time equates to the quantity of product, a packaging variable that was affected by global events. Millisecond timings can have an impact on production; transitioning from 25 ms to 10 ms or even 1 ms in data transmission can result in variations in quantities from 60 g to 6 g or 3 g.

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