Automated system for monitoring and control of the liquid wax production process

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ABSTRACT

This article describes the design of an automated system for the automatic monitoring and control of the liquid wax production process, in order to quantify its effect on productivity indicators. For which initially the procedure for obtaining the automation will be described; then the results obtained will be presented, the same ones that will be identified through a comparative analysis. During the investigation it was determined that, through the use of a programmable logic controller, it was possible to improve the precision of the dosage of components in the liquid wax production process; By achieving a correct dosage, it is achieved that the physical-chemical factors that intervene in the quality of the final product, which are the pH and specific density, are within the limits established by the company, this is reflected in the decrease 38.77% of the amount of monthly loss of raw material, thus achieving the optimization of the productivity of the production of liquid wax by 83.69% per month, compared to the non-automated process.

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1. INTRODUCTION

Increasing competitiveness and globalization require efficient responses from companies, through the use of technological tools, linked to process control and industrial automation, which allow them to guarantee the quality of the production process and reduce production times [1]. Nowadays industrial companies face a more demanding market, it is no longer only the price but also the quality of the product that matters, so much so that many times the customer, because they have a better product, is able to pay the offered price; that is why companies are now seeking a transformation in their production process by using equipment that allows their control and automation [2]-[5]. Thus, the world's organizations seek every day to achieve greater productivity in their production processes in order to be more competitive, for this they design strategies and develop transformations at the operational level making use of industrial automation and process control [6]. The production process, consisting of a machine or installation, equipped with one or more programmable logic controllers reaches a high technological level [7], [8]. Thanks to industrial automation today there are various control strategies capable of making an organization develop in an efficient way so that the industry can work correctly, optimizing production times and accelerating its production process [9]-[12].

Human logic procedures are entrusted to automated machines and computers, which process information much faster than man, thanks to the help of mathematical models that describe both the technology itself and human regulatory activity [13], [14]. Industrial automation is possible thanks to the confluence of various technologies, such as PID controllers (proportional, integrative, derivative), instrumentation, and industrial communication protocols [15]. In this sense, industrial automation is defined as an important tool to optimize processes, reduce operating costs, reduce repetitive activities carried out by personnel in the industrial process, thus increasing productivity; reason for which the decision to carry it out must be preceded by a cost benefit analysis [16]-[19].

Industrial automation comprises technological elements, with the application of mechanical, electronic and computerized systems that allow the operation and control of production with minimal or no human intervention [20]. Thus, at the beginning of the path to automation, the first simple machines substituted one form of effort in another form that was managed by the human being [21]. It is important to highlight that through this type of technology it is not only possible to improve productivity but also competitiveness, since an organization achieves competitive advantages to the extent that an organization manages to use available resources in an optimal way [22], [23].

Thus, industrial automation contributes to a tighter quality control, greater efficiency, increased productivity and a reduction in human labor; This is because scale production involves too many repetitive tasks, as is the case in the liquid wax production process [24]-[26]. At present, the field of liquid waxes is extremely broad, finding a great diversity of characteristics and properties in the way they are produced and in strategy they use to dose the inputs that make up the product [27]-[29]. The production process of liquid wax in many cases lacks the use of technological equipment, which allows its automation and control of the production process, which is why its production and optimization of the use of inputs are affected, which limit it to achieve significant productivity for the company [30], [31].

In this sense, this article aims to describe the design of an automated monitoring and control system, through the use of a programmable logic controller that allows improving the precision of the dosage of components in the liquid wax production process, with the purpose of quantifying its effect on productivity indicators, which should reflect the positive impact on this variable. For which initially the procedure for obtaining the automation will be described; then the results obtained will be presented, the same ones that will be identified through a comparative analysis. It is important to emphasize that as part of the analysis of the data collected, it will be sought to obtain the degree of correlation of the indicators of the only variable under analysis.

2. REASEARCH METODOLOGY

2.1. Design and research level

The research design is experimental, because it influences the production process of liquid wax production, generating an effect on the productivity indicators (amount of useful production and amount of lost production), thus determining a before (non-automated process) and a later (automated process). The research level is descriptive-correlational; It is descriptive because it will detail the method and procedure related to the design of the automated system of the production process of liquid wax production; so that after its implementation the average values of the productivity indicators can be obtained.

2.2. Data collection technique and instrument

The technique used in this research is documentary analysis, because the indicators of the variable under study are part of the production records of the company under analysis; and the instrument used is a record card.

2.3. Validation of collected data

Next, Table 1 shows the reliability results of the information obtained by the data collection instrument. Cronbach's Alpha was used in order to verify the reliability of the data; using the SPSS version 25 software. This analysis was applied to both processes, by using the indicators that make up the productivity variable.

Table 1. Result of the reliability test through Cronbach's Alpha

Indicators in analysis	Cronbach's alpha of the results obtained before automation	Cronbach's alpha of the results obtained after automation
Lost production	0.891	0.834
Useful production	0.889	0.845

3. PROCEDURE AND DEVELOPMENT OF THE AUTOMATION

3.1. Description of the automation

Initially, by pressing the start button, the 3HP and 220 VAC pump (EB1) will be activated for a time of 3 minutes, which will drive the liquid wax, stored in the wax container, towards the Semi Batch reactor; this time will be controlled by a first timer. It is important to point out that at the same moment the pump is activated, the 220 VAC solenoid valve 1 (SV1) will also be activated, the same one that will pass so that the liquid wax reaches the rector; This solenoid valve will actuate for a time of 3 minutes; this time will be controlled by a second timer.

So also, the solenoid valve 2 (SV2), will be activated after 3 minutes, which will allow the access of the solvent (soft water) to the rector; This stage lasts for 5 minutes, this time will be controlled by a third timer; Once these inputs have been entered, the electric stirrer of the reactor will be activated, which will start the mixing stage, for a time of 2 minutes; this time will be controlled by a fourth timer. After stopping the operation of the agitator, the colorant will be entered, which can be yellow, red or black, whose storage tanks are each controlled by a button, so when the solenoid valve (SV3) is activated, the colorant will be entered yellow, when the solenoid valve (SV4) is activated, the red colorant will be entered, or when the electrovalve (SV5) is activated, the black colorant will be entered. This stage lasts 2 minutes; this time will also be controlled by the fourth timer.

Once all the inputs have been deposited, the electric stirrer will be activated again and the steam valve (SV6) will open, which will transfer heat at a temperature of 35 °C, by means of a boiler; This stage lasts for 5 minutes; this time will be controlled by a fifth timer. Once the mixing stage is finished, the drain solenoid valve (SV7) is opened for 10 minutes, this is where the finished product is stored in the wax container, and then goes to the packaging stage, this time will be controlled by a sixth timer. In Figure 1, the diagram of the automated system is shown, in which the working organs (motors, electric pumps and valves) to be controlled are detailed.

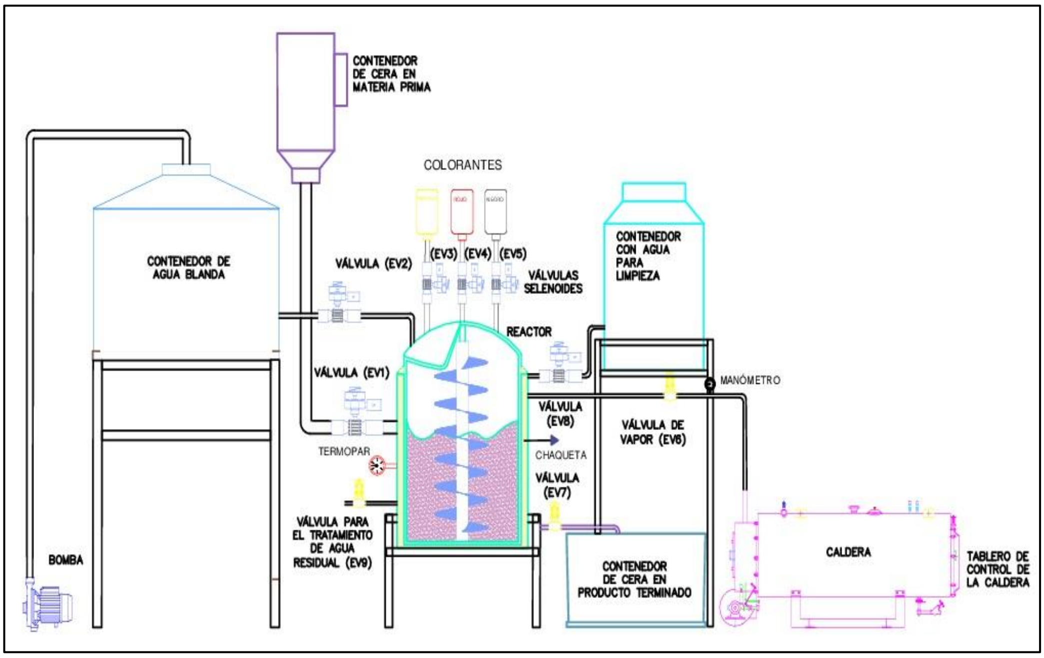

Figure 1. Automatic control system of the liquid wax production process

Continuing with the description of the automated process, I specify that finally, after 10 minutes have elapsed, the cleaning stage of the semi-batch ractor is carried out; In this stage the EV8 solenoid valve is actuated for a time of 5 minutes, which will enter the soft water, which is stored in a container; this time will be controlled by a seventh timer; After the 5 minutes have elapsed, the electric stirrer will be activated, that is where the cleaning stage will proceed, for a time of 5 minutes, this time will be controlled by an eighth timer. It should be noted that once this stage is finished, the EV9 valve is opened for a period of 5 minutes, which will allow this water to be deposited into a storage tank for subsequent residual treatment.

3.2. Description of programable logic controller programming

Once the sensors and actuators had been identified in the production process, the programmable logic controller (PLC) to be used was determined, this being the Siemens simatic 1212C PLC; It should be noted that the three valves used to dose the dyes to the reactor operate with a voltage level of 220 volts AC (alternating current) and in order to be activated by the output signal of the Siemes 1212C controller, whose voltage level is of 24 volts DC (direct current), it will make use of relays from 24 VDC to 220 VAC. Having determined the type of controller below, I describe controller programming, referring to the description made in the previous paragraphs. In Figure 2, the first is the programming segment related to the actuation of the solenoid valve 1 (SV1) and represented by the coil Q0.2 and to the actuation of the 3HP pump represented by the coil Q0.1, both controlled by timer TOF-DB1.

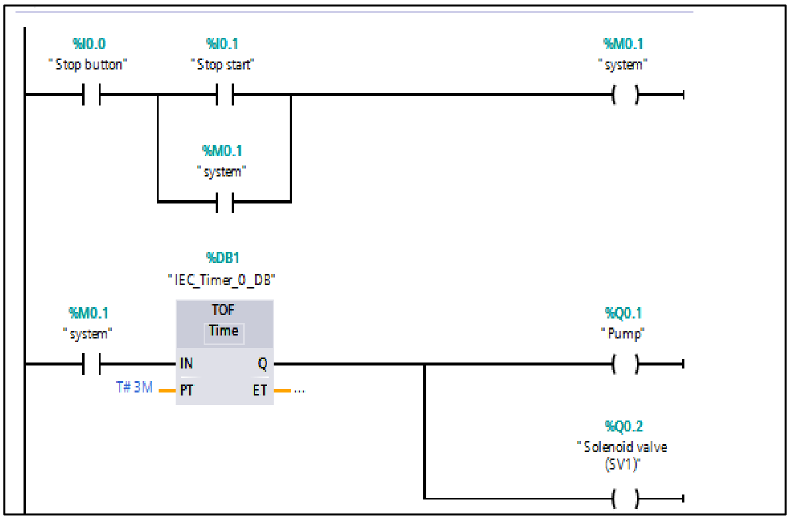

Figura 2. Programming of the electric pump drive and solenoid valve 1

In Figure 3, it is shown in the programming that after 2 minutes of time controlled by the TON-DB2 timer, the solenoid valve 2 (SV2) will be actuated, represented by coil Q0.3, who will pass to the solvent (soft water), towards the reactor; This stage has a duration of 5 min, this time will be controlled by the TOF-DB3 timer.

Once these inputs have been entered, the electric stirrer represented in the programming by the Q0.4 coil of the reactor will be activated, which will start the mixing stage, for a time of 2 minutes, this time will be controlled by the TOF-DB5 timer. It is important to specify that the TON-DB4 timer is used with a time of 7 minutes, whose value is obtained from the sum of TON-DB2 and TOF-DB3. After stopping the operation of the agitator represented by coil Q0.4, the colorant will enter, which can be yellow, red or black; whose storage tanks are each controlled by pushbutton I0.2 (yellow pushbutton), pushbutton I0.3 (red pushbutton) and pushbutton I0.4 (black pushbutton).

So, when activating the solenoid valve (SV3) represented by coil Q0.5, the yellow colorant will be entered, when activating the electrovalve (SV4) represented by coil Q0.6, the red colorant will be entered, or when activating the solenoid valve Q0.7 (SV5), the black colorant will be entered. This stage has a duration of 1 min; this time will also be controlled by the TOF-DB7 (yellow dye), TOF-B8 (red dye), TOF-DB9 (black dye) timers. Once all the inputs have been deposited, the electric stirrer represented by coil Q0.4 will be activated again and the steam valve (SV6) represented by coil Q1.0 will open, which will transfer heat at a temperature of 35 ° C, by means of a boiler, this stage lasts 5 minutes; this time will be controlled by the TOF-DB11 timer. It should be noted that the TON-DB10 timer is set at a time of 10 minutes, it comes from the sum of the times set in the TON-DB6 timer and any of the other timers such as TOF-DB7, TOF-DB8 or TOF -DB9.

In Figure 4, the programming for the normalization of the input of the analog gravity density sensors with input IW0 and PH sensor with input IW2 is shown; in which the normalization is performed over the range of 0-27648; for the gravity density sensor it is scaled from 0 to 1.5 g/ml with ID14 output, and for the PH sensor it is scaled from 0 to 15 with ID18 output

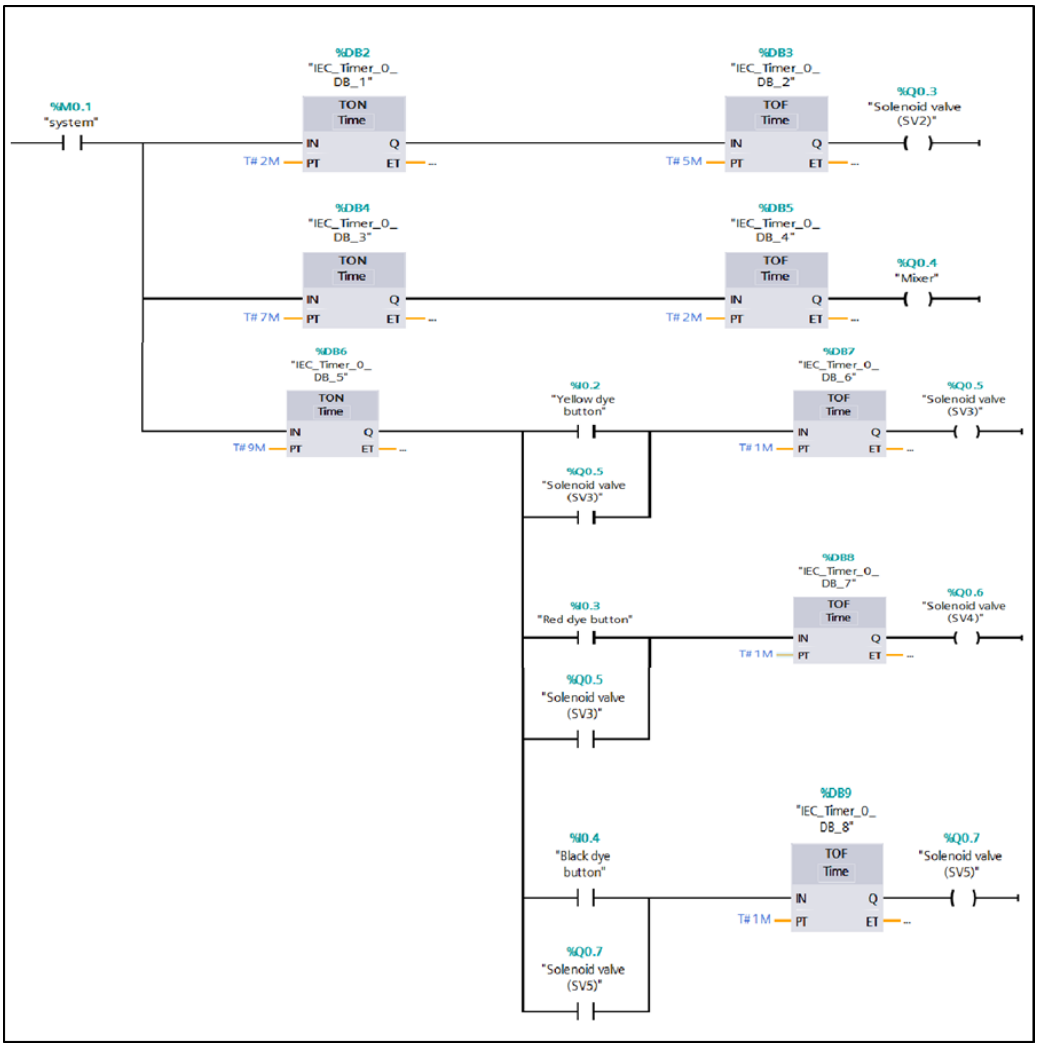

Figure 3. Programming the actuation of the solenoid valve 2 and the agitator

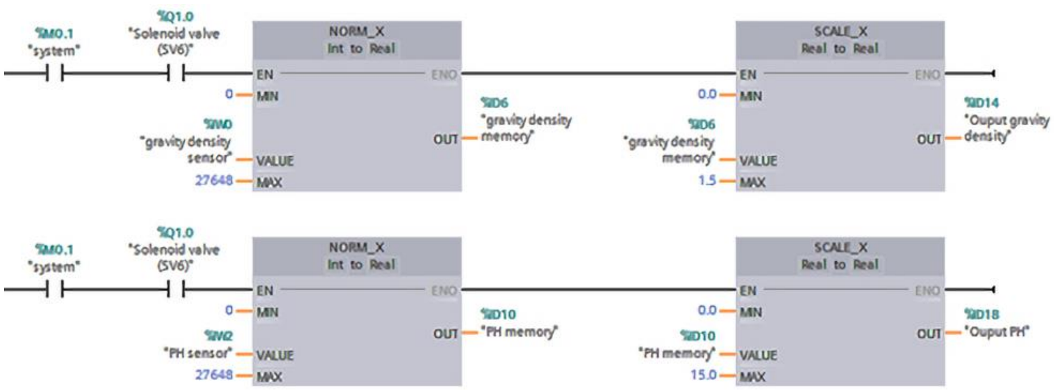

Figure 4. Normalization of the analog sensors of the indicators in analysis

So far, I have partially described the programming of the control system; next, as evidence of the operation of the control system, the operating states are shown through the human machine interface (HMI) system, with which the monitoring and supervision of the indicators under analysis is carried out. In Figure 5, it is shown that the variables that are part of the control system, such as the PH of and the gravity density, are within the ranges established by the quality control area, which guarantee the obtaining of a quality product.

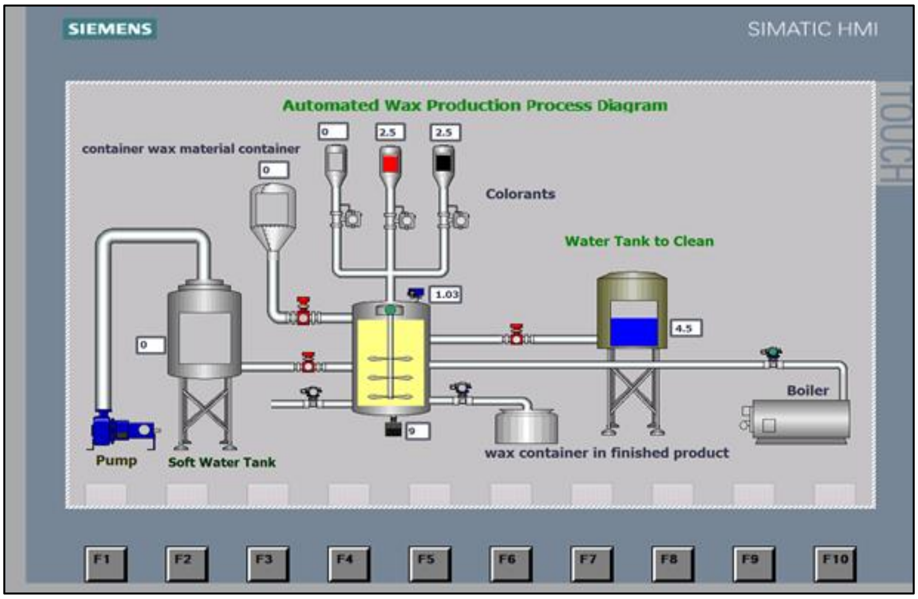

Figure 5. HMI interface of the automatic control system of the liquid wax production process

4. RESULTS AND DISCUSSION

4.1. Results

The optimization of the production process is related to the increase in the amount of liquid wax production and the decrease in the level of raw material lost during the process; Likewise, production is closely related to the quality of the product, said quality will be measured by means of two potential indicators of hydrogen (pH) and the specific gravity of the solution. Figure 6 shows the results obtained from the variation of the PH, using the automated process, it should be noted that the dotted lines indicate the setpoint range for the controlled variable.

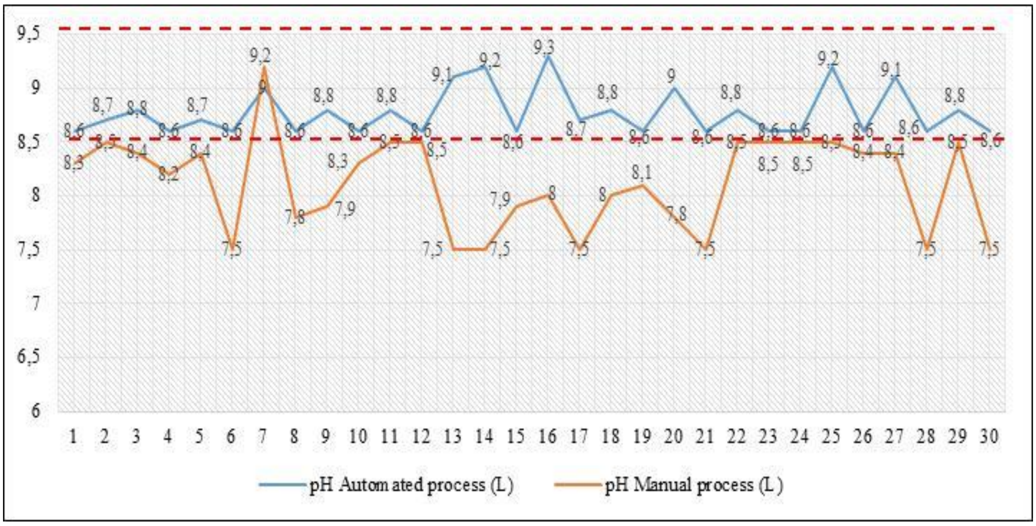

Figure 6. Results of the regulation of the hydrogen potential (PH)

Figure 6 reveals that, when implementing the automated process, the PH is within the permissible values of 8.5-9.5, established in the preparation of red, yellow and black liquid wax. For this reason, it is pointed out that the percentage of the hydrogen potential presents a monthly improvement of 8.04%, compared to the non-automated process. Next, Figure 7 shows the results obtained from the variation of specific gravity, once the automated process has been applied. It also shows that when implementing the automated process, the specific gravity of the solution is within the permissible values of 0.990-1.006. For this reason, it is pointed out that the percentage of specific gravity presents a monthly improvement of 4.4%, compared to the non-automated process.

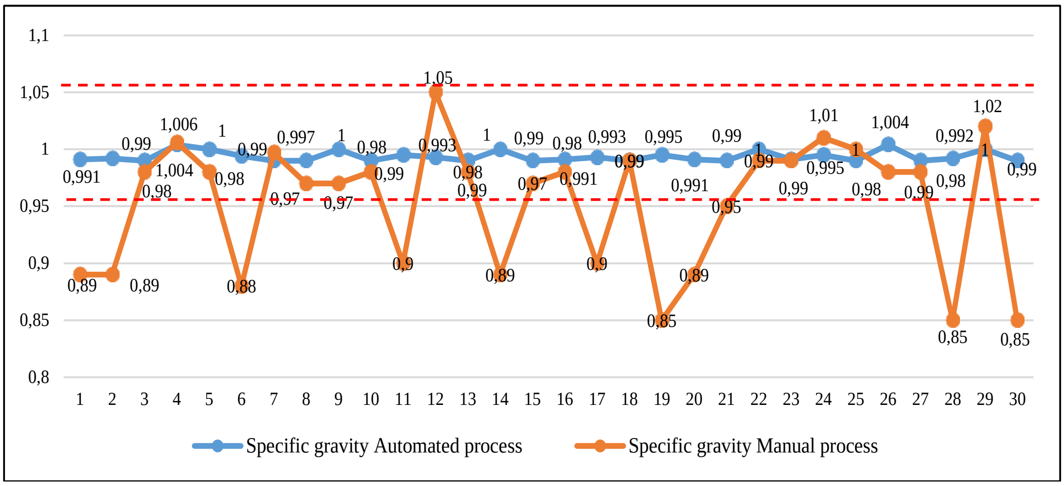

Figure 7. Results of the regulation of specific gravity

By regulating the physical chemical indicators, through the automatic monitoring and control system, these will be reflected in the improvement of the quality of the final product, thus optimizing the productivity of the liquid wax manufacturing process; achieving a decrease in the loss of raw material during the production process, from the data collected it is determined that the monthly optimization turned out to be 38.77% in relation to when the process was not automated. Also, regarding the improvement of the useful production indicator, it was determined that this indicator presented a monthly improvement of 83.69%, compared to the non-automated process.

4.2. Correlation of results

At this point, the level of relationship that exists between productivity indicators and physical-chemical factors will be determined; For this, it must be taken into account that to affirm that there is a correlation, sig. (Bilateral) must be less than the significance of α, which is equal to 0.05. Furthermore, if the value of the correlation is between 1 to 0.8 or from -1 to -0.8, it indicates that there is a very high correlation.

Given what has been described, and according to the results observed in Table 2, the degree of correlation for all cases is greater than 0.805, therefore it is indicated that there is a high and significant relationship between the indicators of the productivity variable (useful production and production loss) with the physicochemical factors that define the quality of the product (pH and specific gravity).

Table 2. Results of pearson's correlation test

Indicators in analysis	Lost production	Useful production	pH	Gravity specific
Lost production	1	0.833	0.843	0.856
Useful production	0.833	1	0.805	0.856
pH	0.843	0.805	1	0.824
Gravity specific	0.856	0.856	0.824	1

4.3. Discussion

As observed when applying the automated monitoring and control system, it is possible to optimally regulate the physical-chemical factors that intervene in the quality of the final product, this generates that it is possible to reduce the amount of monthly loss of raw material by 38.77%, which at the same time, it is reflected in the increase in the useful productivity of the preparation of liquid wax, this monthly optimization is 83.69%. These results are similar to those obtained in the study by [32], where it is pointed out that the average physical-chemical characteristics obtained through the automatic control by fuzzy logic of the cooking and maceration stages were: density of 0.9825 g/cm^3; pH 3.9013; percentage of total acidity expressed in lactic acid of 0.8743%, alcoholic degree of 6.244 ºGL and a percentage of CO_2 of 0.914% w/v, all these surfaces being within the established by the Technical Norm Nº 213.014-Peru. Also, in [33]-[35], it is specified that when using an automatic control system, productivity indicators increase significantly, this because the use of controllers improves the precision of the inputs to be used in the production process of liquid wax.

In addition, when determining that there is a significant correlation between the indicators lost production, useful production, pH and Gravity specific, it is evidenced that the productivity variable was linked through the automated system with the indicators pH and Gravity specific, whose level of correlation is significant; In this regard, Barreto *et al.* [28] and Ramirez [34] corroborate the finding by determining since in their research they determine that there is a significant direct relationship between the PH indicators and specific gravity with respect to the productivity indicators centered on the quality of the final product.

5. CONCLUSION

Through the use of a programmable logic controller, it is evident that it was possible to improve the precision of the dosage of components in the liquid wax production process; Thus, it was also evidenced that as a consequence of a correct dosage, it is achieved that the physical-chemical factors that intervene in the quality of the final product, which are the pH and specific gravity, are within the limits established by the company. It is reflected in the 38.77% decrease in the amount of monthly loss of raw material, thus achieving the optimization of the productivity of the production of liquid wax by 83.69% per month. It is concluded that from the data collected after the implementation of the automated system for monitoring and control of the liquid wax production process, it is possible to link the productivity indicators with the dosage indicators, this determined from the level of significant direct correlation.

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