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Chrono-analysis: Study applied to a processing unit of swine in Brazil

Cronoanálise: Estudo aplicado a uma unidade processadora de suínos no Brasil

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ABSTRACT

Continuous improvement methodologies for industrial food processes are critical for keeping competitiveness and offering food with lower costs and appropriate quality. Therefore, this study aimed to analyze the operational procedures of deboning and Tuscan sausage sectors in Brazilian's swine meat industry by employing Chrono-analysis tools. An industrial case study was carried out in a large swine industry in Brazil. The findings show that the production activities of deboning and Tuscan sausage have short lead times, and the average monthly production of the analyzed products is within a range considered regular. There was a possibility of joining some activities developed, equaling the workload, and reducing the workforce. The study observed conditions for productivity improvement in both sectors analyzed. Also, our findings showed that classical and comprehensive knowledge techniques on Operations Management could bring performance gains. This scenario could be explained from the Practice-Based View lens when environmental characteristics and handling of internal assets are determinants for manufacturing improvements practices deployment and success. Productivity gains and cost savings observed in our study are the basement for both lower prices and reliability on food chains, showing immediate social benefits from our study.

Keywords: Food industry. Meat processing. Line balancing. Productivity.

RESUMO

Metodologias de melhoria contínua dos processos industriais de alimentos são fundamentais para manter a competitividade e oferecer alimentos com menor custo e qualidade adequada. Portanto, este estudo tem como objetivo analisar os procedimentos operacionais dos setores de desossa e linguiça toscana em uma indústria de carne suína no Brasil, por meio do emprego de ferramentas de cronoanálise. Os resultados mostram que as atividades de produção de desossa e linguiça toscana apresentam lead-times curtos, sendo que a produção média mensal dos produtos analisados está dentro de uma faixa considerada regular. Houve a possibilidade de agregar algumas atividades desenvolvidas, balanceando a carga de trabalho e reduzindo a força de trabalho. O estudo observou condições para melhoria da produtividade nos dois setores analisados. Além disso, nossos resultados mostraram que técnicas clássicas e amplamente conhecidas em Gerenciamento de Operações podem trazer ganhos de desempenho. Este cenário pode ser explicado a partir da lente da Visão Baseada na Prática, quando as características

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ambientais e o manuseio de ativos internos são determinantes para a implantação e o sucesso das práticas de melhoria de fabricação. Ganhos de produtividade e economia de custos observados em nosso estudo são a base para preços mais baixos e confiabilidade nas cadeias alimentares, expressando benefícios sociais imediatos a partir da pesquisa.

Palavras-Chave: Frigorifico. Processamento de Carnes. Balanceamento de Linha. Produtividade.

1 INTRODUÇÃO

According to the Brazilian Association of Swine Producing and Exporting Industry (ABIPECS, 2014), swine meat volume in 2014 was 39,026 tons in March, 5,65 % higher than in February of the same year (36940 ton.). In March 2014, revenue grew 8,27 % and reached US$ 104,52 million, compared to US$ 96,54 million in February. The average price followed an upward trend, rising 2,48 % in comparison with February 2013. The Brazilian swine market is continually expanding. In 2013, Brazil was the 4th largest world producer in this market segment, with approximately 3 million and 227 thousand tons. 2013. After three years, from 2014, Brazil has left the stagnation in swine consumption, and during 2018, it consumed more than 14,8 kg per capita of the product (DEPEC, 2019).

The consumption of swine-based food has exponentially grown from the COVID-19 outbreak, home-office tasks, and social isolation (see McEwan 2020). This scenario made a run for commodities, causing shortages and high prices from producers. Another problem caused by the COVID-19 outbreak is animal consumption by farmers due to a lack of income for food (e.g., in China). This scenario has been affected the supply chain in the offer (lack of animals) and unstabilizes the demand (an increase of prices and shortage). For an in-depth view about swine market behavior in one of the main producers, the U.S., sees Hayes et al. (2020). In lastly, besides that COVID-19 crisis, the swine industry has been affected by the combination of African swine fever, which according to Woonwong et al. (2020) will continue to affect World' swine production in 2021. However, demand is expected to recover in most markets (RABOBANK, 2021).

The current trend of increasing efficiency in all types of activities has aroused interest in studying times, movements, and swine agribusiness methods. Wherever manual labor is applied, there is always the problem of finding the most economical way to perform the task and determine the amount of work performed in a given period (BARNES, 1980). The study of times and moves provide techniques to determine the standardization and the most economical methods of execution and measurement of the work performed (TOLEDO Jr., KURATOMI, 2004b).

Therefore, this work aims to realize a study for times and Chrono-analysis in a swine slaughterhouse in Nova Mutum, Mato Grosso State, Brazil, more specifically in the sectors of deboning and the Tuscan sausage. For this, the study identified process' flowcharts, defined the Standard Time (ST) for operations analyzed, the calculation of productivity, and line balancing. The main managerial contributions brought by our study refer to productivity improvements from the adoption of classical and straightforward Times and Moves tools like Chrono-Analysis. With regards to theoretical contributions, our findings evidence that the improvement programs adoption and running are a catalyst of performance gains (e.g., lead time and productivity). This finding can be supported by the Practice-Based View (PBV— Bromiley and Rau, 2016), which explains that even practices of the wide domain in a sector can be replied to over specific conditions within a company performance benefits. In last, our research presents a clear roadmap (steps, tools, mapping, analysis procedures) for both an initial Times and Moves study and continuous improvement initiatives in the swine-based food industry.

1.1 Motion and Time studies

Human labor can be defined as any physical or mental activity performed by a human being whose objective is to do, transform, or obtain something (TOLEDO Jr., KURATOMI, 2004a). In a broad sense, work is all human activity that transforms a product or service from a given material or input. The word is derived from the Latin "tripaliare", which means to torture, which is responsible for the idea of suffering or struggling and, finally, working or acting (TOLEDO Jr., KURATOMI, 2004b). In an economic sense, work is all the activity performed by a man on raw material, usually with instruments, with the main objective of producing goods and services (PARKER; WALL; 1998).

The study of times and movements is the systematic study of work systems to develop the system and the preferred method, standardizing that system and method, determining the time spent by a qualified and trained person, at an average pace to perform a specific task, and guide the training of the worker in the most appropriate method (MOURA; LIU, 2014). These steps are known in industrial practice as Chrono-Analyse.

The study of times and movements has two main parts, and they are Move Study or Design of Methods and Times and Movies Study or measure of work (TOLEDO Jr., KURATOMI, 2004a). The first is related to finding the best method to perform the task, and the second is the one addressed in this work, which is related to the determination of the standard time to perform a specific task (KURODA et al., 2018).

1.2 A brief literature review

Motion and Time studies tools like Chrono-analysis are usual methods used in Labor Engineering to triggering measurement programs and supporting to handle continuous improvement parameters through manufacturing systems (machines, people, supplies, materials, and products). Traditional Movies and Times offer powerful tools for labor analytics on strongly worker-based production (BARNES, 180).

Currently, the food industry competition is global (NIEMI et al. 2020). Methods, tools, and programs for continuous improvements are primer- order to competitive advantages and survival along with swine industry (TOKACH et al. 2016). Therefore, a Chrono-analysis study and corrective procedures proposition is the first step to production improvement initiatives based on measurement and identification of labor elements within the industrial swine process (MOURA, LIU, 2014; KURODA et al. 2018).

According to Table 1, many initiatives are carrying out around the World concern improvement performance in the swine industry and supply chain. Most of these studies focus on performance improvements and supply chain integration (NDWANDWE, WENG, 2018; PAIRIS-GARCIA, RADEMACHER, 2016). Sustainability, wasting, and pollution is a current and important factor in the swine industry improvement initiatives and costs determination along with performance ((NDWANDWE, WENG, 2018; de CAMARGO et al., 2016). Technological factors, benchmarking, and improvement tools are proved to increase the performance in the swine industry (TOKACH et al., 2016). Also, focused improvement tools linked to the handling of swine along the supply chain are a determinant financial factor in the industry competitivity (NIEMI et al., 2020). However, from these studies surveyed, the present study was not verified findings from industrial-case Chrono-analysis applying in the swine industry. Therefore, our study helps understand how to apply and derived results from Chrono-analysis handling in swine meat processing units over the Brazilian industrial conditions.

Table 1: Studies about production improvements initiates in the swine industry around the World

Literature	Description
Pairis-Garcia and Rademacher (2016)	A framework based on the Pork Quality Assurance®Plus program was developed for a single, common audit platform for the US Pork Industry. This study assesses the audit's goal to provide useful feedback for continuous improvement on the farm to the industry supply chain. The study claims that the industry is committed to utilizing the information attained through on-farm audits to develop the educational tools, resources, and support to advance on-farm swine welfare, supporting the industry performance indicators.
Tokach et al. (2016)	This study focuses on performance-enhancing technologies in swine production as a continuous improvement program. The findings showed that by applying improvement tools, the swine market requires 4% less feed today to produce a 17% heavier carcass than they did 25 years ago. Other technological changes refer to as Operations Management, which now encompasses "modern swine production," are perhaps even more critical. Advancements in record-keeping, benchmarking, refinements in nutrient requirements, biosecurity, and increased sizes of meat-processing facilities have also contributed to increased productivity.
Ndwandwe and Weng (2018)	This study used a survey and SWOT analysis to assess the current swine production and market performance of smallholder farms in Swaziland. In order SWOT factors quantifying, the Analytical Hierarchy Process (AHP) was used to derive priorities for the subsequent formulation of potential swine production strategies that are resilient both to market and climate changes. For strategy formulation, this research applies Porter's cost leadership strategy. The research findings revealed that the pig industry in Swaziland is attractive and that the present is probably the best time for smallholder farmers to maximize their profits. Unfortunately, according to the authors, the industry was found to be threatened by the expected increase in production capacity, future market competition, and the socio-environmental challenges associated with expansion. Despite this, the findings suggest that smallholder farmers can survive future market challenges by strategically using agro-industrial by-products as alternative feed ingredients to reduce production costs. The formation of farmers' associations could benefit smallholder farmers through economies of scale, processing, and product value addition, and increased access to markets, and unity could strengthen their position in the market when bargaining for better prices.
Camargo et al. (2018)	It discusses the application and the results of a Sustainability Indicators System in the swine industry in the Brazilian State of Santa Catarina. The research built indicators focused on the level of sustainability maturity and can be used to diagnose and compare the industry's efficiency from a broader perspective of continuous improvement.
Niemi et al. (2020)	This research calculates from Value chain analysis (VCA) the financial effects on food chain actors of interventions to improve animal health and welfare in the intensive swine sector in Finland. This study handling two interventions to reduce swine production diseases were studied. The most beneficial intervention in financial terms to farmers was improved hygiene in swine fattening (around +50% in gross margin). It was calculated to reduce the consumer price for pig meat by up to 5% when applied at large, whereas for improved management measures, it would reduce consumer price by less than 0.5%. However, the latter added value also through food quality attributes. This study shows that good hygiene and animal care can add value. Supply chain structure influences which policy measures could be applied in Finland. Of the two interventions, improved pig hygiene had the largest potential to improve efficiency and reduce costs (indicators improvement).

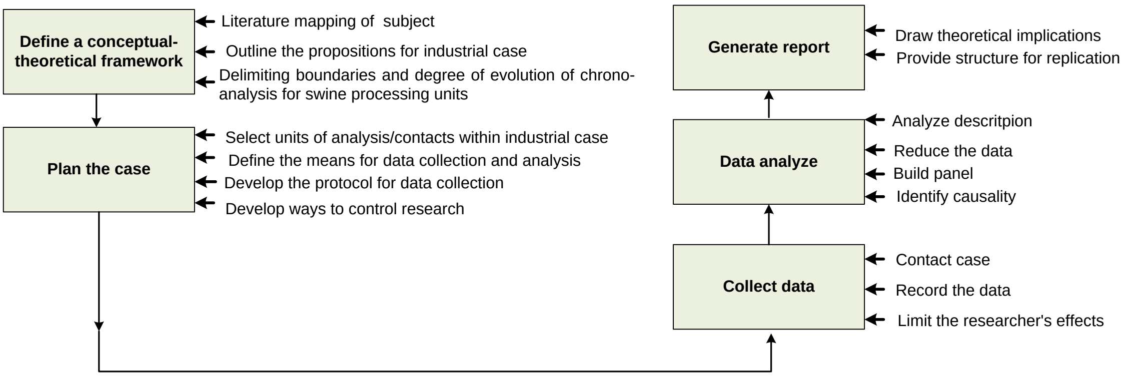
2 RESEARCH METHODOLOGY

Before starting the times' data collection in the deboning and sausage sectors in the meat processing industry studied, was realized an operations mapping. To better understand the processes involved, a design of the macro-process flowcharts, products, activities flow, and a mass balance on each plant sector was carried out (see Figures 2 and 3). These steps are needed to understand dimensions, inputs, and outputs entities and map actions within Chrono-analysis planning and execution.

This research is classified as an Industrial Case study from an empiric and descriptive approach (MIGUEL, 2007). Our choosing Case Study due to the requirement of the most profound investigation of phenomenon research from a specific industrial environment: the swine industry. This industrial case is representative of our problem investigation. Our study follows a research methodology, according to Yin's (2017) guidelines for case research and Miguel's (2007) steps (Figure 1).

After specifying the research design procedure, the data collection was carried out through a brief literature survey (Chrono-analysis protocol for deployment in the meat industry), workshops with managers and sector workers, in loco observations (direct observations for times measure, and flowcharts design), documents (database and ERP data), and ad hoc production sheets of both industrial activities: deboning (studied in May 2013) and Tuscan sausage (studied in April 2014). These data collection procedures were supported by an industrial study case protocol (Yin, 2010). To obtain the data, the research used the following devices necessary to study times and moves (TOLEDO Jr., KURATOMI, 2004a), one digital centesimal stopwatch, a clipboard, and a verification sheet (Appendix A). During the observations, the operators would have their times analyzed were randomly selected.

Figure 1: Industrial case study methodology (steps and procedures)



Source: Miguel (2007)

The technique used for measuring the samples was the Timing, which is the technique of obtaining the times necessary to complete a specific process and adopt parameters (SLACK, CHAMBERS; JOHNSTON, 2010). Chrono-analysis is a relatively simple technique. It consists of selecting an operation to be analyzed with a stopwatch to perform the collection of the time elapsed until the end of it (CAMAROTTO, 2007). In possession of the times, they transferred to an electronic spreadsheet for normalization and standard time determination. After, applied the equations 1, 2, 3, and 4 below (TOLEDO JR.; KURATOMI, 2004a) for Normal Time derivations. The data collection periods took place at specific times for two years: May 2013 and April 2014.

$$\mathrm{NT} = \mathrm{RT} * \frac{\mathrm{EF}}{100} \tag{1}$$

NT is the Normal Time, and RT is the Real-Time, EF is the Operator Efficiency in percentage. If the task is divided into n elements, the NT will be determined according to Equation 2:

$$\mathrm{NT}i = \mathrm{RT}i * \frac{\mathrm{EF}i}{100} \tag{2}$$

Where RTi and NTi are the individual times that compose the Normal Time and Real-Time, respectively. Also, EF is the efficiency of the evaluated operator in the execution of an element i. Besides, NT is the result sum's of all normal-time for i-elements involved in the activity, according to Equation 3:

$$\mathrm{NT} = \sum \mathrm{RT}i * \frac{\mathrm{EF}i}{100} \tag{3}$$

Once the Normal Time has been obtained, it was proceeded with the calculation of the Standard Time, which according to Toledo Jr. and Kuratomi (2004a) can be determined through Equation 4, where the Tolerance Factor must be taken into account:

$$\mathrm{ST} = \mathrm{NT} * \mathrm{TF} \tag{4}$$

The ST is the Standard Time, NT is Normal Time, and TF is the Tolerance Factor.

The standard time was obtained, and information gathered, performing all other calculations required for Chrono-analysis such as line balancing (Equations 5 and 6) and productivity (Equation 7). It is worth mentioning that applying these methodologies of analysis was made only in activities useful for obtaining four main products of the company: filet, loin chop, sawn rib, and Tuscan sausage.

For balancing a production line correctly, some steps must be followed (TOLEDO JR.; KURATOMI, 2004a):

Step 1- Calculation of the Manpower Load (ML) for the number of workers:

$$ML = ST\ \text{by piece} * \frac{\frac{\text{production}}{\text{day}}}{\frac{\text{working time}}{\text{day}}} \quad (5)$$

Step 2- Determination of balanced ST:

$$ST_{\text{balanced}} = \frac{ST\ \text{by piece}}{n^{o}\ \text{workers}} \quad (6)$$

Where ST is the Standard Time of the piece. Our study adopted the following criteria for the definition of workstations: if the operation's ST is equal to the balanced ST, this activity will be a workstation. If the operation's ST is less than the balanced ST, there is a need to join the activities to have no workstation idleness. Besides that, when the ST of the operation is greater than the balanced ST, it is necessary to supplement it with overtime, enabling daily production fulfillment.

3 INDUSTRIAL CASE: INDUSTRY MEAT PROCESSING

The meat processing industry (named now Industry X) was opened in 1998 in the Nova Mutum, Mato Grosso State, Brazil. It is a company specialized in the slaughter of swine and the industrialization of derived products, selling to Brazil and abroad. The industry has 21,250 m² of built area, nearly 3,000 employees (these are data for the years 2013 and 2014). Industry X has an installed capacity to slaughter 3,000 animals/day (350 swine/hour). There is a capacity for deboning for 250 animals/hour in the deboning sector, and the industrialized sector can produce 100 tons. /day, divided into fresh, cooked, and seasoned products.

4.1 Process flowchart: deboning of the balanced lines

The deboning sector was one of the chosen ones for this study due to its significant dependence on manual labor, where its production performance is directly influenced by the execution times of the activities performed by the collaborators. This sector can be subdivided into five parts (see Figure 2): entrance to deboning, mezzanine, table/platform of the ham, table/platform of the palette, and secondary cuts and packaging.

Figure 2: Deboning shop floor: machines and equipment


a) Entrance to deboning b) Mezzanine


c) The platform of Ham d) Platform of the palette

e) Secondary cuts

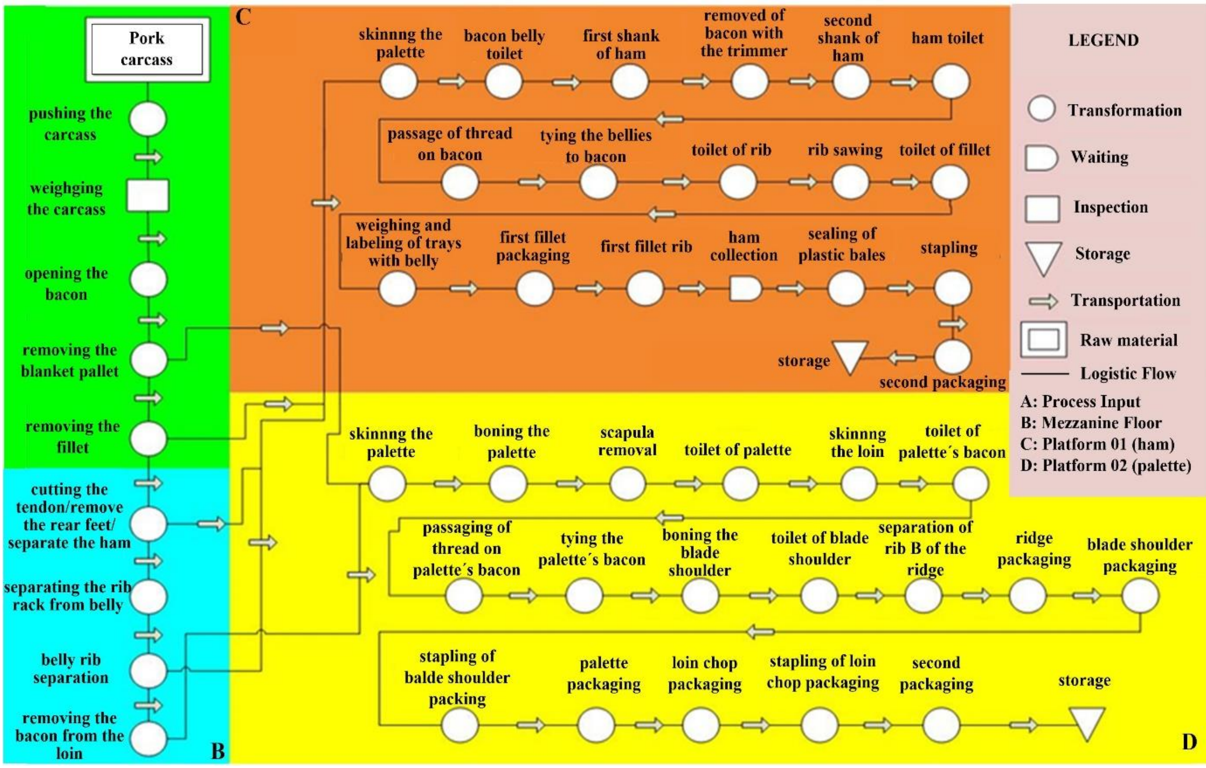
Source: Field Research (2015)

The entrance to deboning is the place where swine carcasses are removed from the storage sector (cold chambers), and they are taken to the carcass quality inspection area, carried out by the Brazilian Federal Inspection System (SIF), to be weighed later on a suspended scale and sent to the deboning sector. At the entrance to the deboning sector, the removal of meat pieces begins, with the first piece being the palette blanket and the palette, where the palette goes to platform 01, and the blanket is destined to a device called skinner to remove the meat skin. At the entrance to the sector, the fillet is also removed, placing these pieces in trays, and after they are full, they are cutting into other pieces and packing on platform 02 for the performance of other activities related to this cut.

The mezzanine is a rolling platform with three electric saws, where the primary cuts are made, and the carcass is divided into shank, rib, loin chop, and loin. It is from the mezzanine that the separate pieces are destined for platforms 01 and 02 for making secondary cuts; that is, products that arose from boning are separated in the mezzanine, with ham, rib, and belly being sent to platform 01, and chop loin and loin at platforms 02. Platform 01 is where the secondary cuts of the ham, rib, and belly are made.

After making secondary cuts on platform 01 and 02, the products from both platforms are packed on a conveyor belt and sent to the secondary packaging sector, where they will be placed in cardboard boxes, weighed, labeled, and then packed in cages and sent to the freezing tunnels, only to then be made available in stock. Figure 3 presents a general flowchart of processes with all activities performed in the deboning sector.

Figure 3: Deboning processes flowchart



Source: Field Research (2015)

4.2 Process flowchart: Tuscan sausage line

Tuscan sausage production was chosen as regards its great importance to the company. It is responsible for most individual sales and is considered the "flagship" of the company.

The Tuscan sausage production sector can be subdivided into two smaller sectors, facilitating the study of the times that is compound by machines and equipment illustrated in Figure 4. The first sausage sector is Dough preparation, i.e., where the meat (raw material) and seasonings are prepared and mixed. From this, then forming the Tuscan sausage dough, and the meat is collected in metal conveyors; after sending it to the grinder, some meats that are frozen go through a block breaker; before being sent to the grinder, the ground meats are taken to the mixer, where they also condiments and water are added.

The Inlay processing happens after the mixture is homogeneous, then it is taken to the maturation silo, employing an elevator, where it remains from 12 to 96 hours and is destined for inlay. The operations for Tuscan sausage are shown in Figure 5.

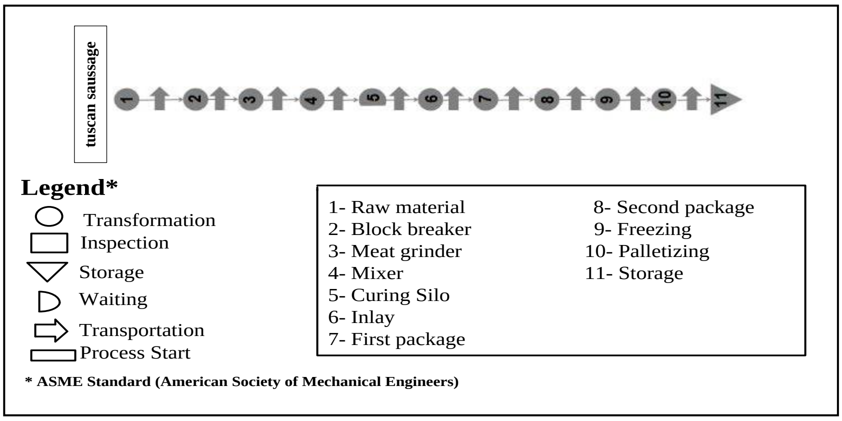
Figure 4: Tuscan sausage installation: machines and equipment

a) Trolley for dough transfer b) Industrial meat grinder c) Crusher

d) Industrial mixer e) Trolley f) Silo

Source: Field Research (2015)

Figure 5- Tuscan sausage process flowchart



Source: Field Research (2015)

4.3 Standard Time calculation

The following Tables 2 and 3 show the activities that make up the Tuscan sausage production sector and deboning well with its elements and respective standard times, which should be a reference, in the respective sectors, for productivity, balancing lines and saving resources of Industry X. In possession of the standard time, the company can execute policies and procedures on productivity, training of labor, redefinition of the layout.

Table 2: Times of the deboning process (by each operation)

Elements	Real-Time	Westinghouse System		Normal Time	Standard Time
		Skillful	Effort		
pushing the carcass	42 s	0,00	0,00	42 s	48 s
weighing the carcass	11 s	+ 0,03	0,00	11 s	12 s
opening the bacon	11 s	+0,03	0,00	11 s	13 s
removing the palette blanket	14 s	+0,06	0,00	15 s	17 s
removing the fillet	9 s	+0,06	0,00	11 s	11s

a) Times of deboning entry elements

Elements	Real-Time	Westinghouse System		Normal Time	Standard Time
		Skillful	Effort		
cutting the tendon; remove the rear feet; separation of ham	13 s	+0,06	+0,02	14 s	16 s
hip removal	4 s	+0,11	0,00	4 s	5 s
separating the rib sawn from the belly	10 s	-0,05	0,00	9 s	10 s
belly rib separation	11 s	+0,11	-0,04	12 s	14 s
removing the bacon from the loin	4 s	+0,08	0,00	4 s	5 s

b) Times of mezzanine elements

Elements	Real-Time	Westinghouse System		Normal Time	Standard Time
		Skillful	Effort		
skinning the palette	6 s	+0,06	+0,02	6 s	7 s.
deboning the palette	38 s	+0,03	0,00	39 s	45 s
scapula removal	10 s	+0,06	0,00	11 s	12 s
toilete of palette	17 s	0,00	0,00	17 s	19 s
skinning the loin	7 s	0,00	+0,05	8 s	9 s
toilete of bacon	13 s	0,00	0,00	13 s	15 s

Elements	Real-Time	Westinghouse System		Normal Time	Standard Time
		Skillful	Effort		
toilete of palette´s bacon	8 s	+0,08	0,00	8 s	10 s
passaging of thread on palette´s bacon	3 s	+0,08	0,00	3 s	3 s

c) Times of palette elements

Elements	Real-Time	Westinghouse System		Normal Time	Standard Time
		Skillful	Effort		
boning the blade shoulder	11 s	+0,06	0,00	12 s	14 s
toilet of blade shoulder	15 s	0,00	0,00	15 s	17 s
separation of rib B of the ridge	4 s	+0,03	+0,02	4 s	5 s
ridge packaging	29 s	-0,10	0,00	26 s	30 s
blade shoulder packaging	6 s	+0,08	0,00	6 s	7 s
stapling of blade shoulder packing	6 s	+0,03	+0,02	6 s	7 s
palette packaging	2 s	+0,03	0,00	2 s	3 s
loin chop packaging	14 s	-0,10	0,00	13 s	14 s
stapling of loin chop	10 s	+0,03	0,00	10 s	12 s
boning the blade shoulder	11 s	+0,06	0,00	12 s	14 s

d) Times of palette elements (cont.)

Elements	Real-Time	Westinghouse System		Normal Time	Standard Time
		Skillful	Effort		
skinnng the palette	11 s	0,00	0,00	11 s	13 s
bacon belly toilet	7 s	+0,03	0,00	7 s	8 s
skinning of belly for bacon	9 s	0,00	0,00	9 s	11 s
first shank of ham	25 s	+0,11	-0,04	26 s	30 s
removed of bacon with the trimmer	12 s	+0,03	0,00	13 s	15 s
second shank of ham	30 s	+0,08	0,00	33 s	38 s
ham toilet	53 s	0,00	0,00	53 s	1:10 min.

e) Times of ham elements

Elements	Real-Time	Westinghouse System		Normal Time	Standard Time
		Skillful	Effort		
passage of thread on bacon	2 s	+0,08	0,00	3 s	3 s
tying the bellies to bacon	5 s	+0,03	0,00	5 s	6 s
toilet of rib	4 s	+0,08	+0,02	5 s	5 s
rib sawing	5 s	+0,03	0,00	5 s	5 s
toilet of fillet	9 s	0,00	0,00	9 s	10 s
weighing and labeling of trays with belly	11 s	+0,03	+0,02	12 s	13 s
first fillet packaging	16 s	0,00	0,00	16 s	18 s
first fillet of rib	9 s	+0,08	0,00	10 s	11 s
ham collection	2 s	0,00	0,00	2 s	2 s
sealing of plastic bales	9 s	0,00	0,00	9 s	10 s
stapling	9 s	+0,08	-0,04	9 s	10 s

f) Times of ham activities (cont.)

Source: Field research (2015)

Table 3: Times of Tuscan sausage process (by each operation)

Elements	Real-Time	Westinghouse System		Normal Time	Standard Time
		Skillful	Effort		
trolley lift and return	38 s	0,00	0,00	38 s	40 s
time to grind fat flap	01:56 min.	0,00	0,00	56 s	02:01 min.
carriage displacement time for the mixer	10 s	0,00	0,00	10 s	11 s
trolley lift and return	38 s	0,00	0,00	38 s	40 s
time to grind fat flap	03:04 min.	0,00	0,00	03:04 min.	03:14 min.
carriage displacement time for the mixer	10 s	0,00	0,00	10 s	11 s
trolley lift and return	38 s	0,00	0,00	38 s	40 s
time to grind fat flap	01:56 min.	0,00	0,00	56 s	02:01 min.
carriage displacement time for the mixer	10 s	0,00	0,00	10 s	11 s
trolley lift and return	38 s	0,00	0,00	38 s	40 s
time to grind fat flap	03:04 min.	0,00	0,00	03:04 min.	03:14 min.

a) Times of grinder elements

Elements	Real-Time	Westinghouse System		Normal Time	Standard Time
		Skillful	Effort		
pick up package (20 kg)	11 s	0,03	0,00	11 s	12 s
crusher time (20 kg)	10 s	0,03	0,00	10 s	10 s
pick up package (20 kg)	10 s	0,03	0,00	10 s	11 s
crusher time (20 kg)	10 s	0,03	0,00	10 s	10 s
moving the trolley with crushed to the scale	6 s	0,03	0,00	06 s	07 s
weighing	3 s	0,03	0,00	03 s	03 s
flap collection time (fat)	2:08 min.	-0,10	-0,04	01:50 min.	01:56 min.
weighing	36 s	-0,10	-0,04	31 s	32 s

b) Times of shredder / fat flap elements

Elements	Real-Time	Westinghouse System		Normal Time	Standard Time
		Skillful	Effort		
Mixer	6:00 min.	0,00	0,00	0 s	06:18 min.

c) Times of shredder elements

Elements	Real-Time	Westinghouse System		Normal Time	Standard Time
		Skillful	Effort		
flap collection time (thin)	2 min.	0,03	0,00	2:02 min.	2:08 min.
second-time measurement for flap collection (thin) trolley	2 min.	0,03	0,00	2:02 min.	2:08 min.
weighing	16 s	0,03	0,00	17 s	18 s
flap collection time (thin)	2 min.	0,03	0,00	2:02 min.	2:08 min.
second-time measurement for flap collection (thin) trolley	2 min.	0,03	0,00	2:02 min.	2:08 min.
weighing	16 s	0,03	0,00	17 s	18 s

d) Times of shredder / slim flap elements

Elements	Real-Time	Westinghouse System		Normal Time	Standard Time
		Skillful	Effort		
fill cart in silo	12 s	0,06	0,00	13 s	13 s
silo / scale displacement	14 s	0,06	0,00	15 s	15 s
weighing	15 s	0,06	0,00	16 s	17 s

Elements	Real-Time	Westinghouse System		Normal Time	Standard Time
		Skillful	Effort		
scale / filler displacement	11 s	0,06	0,00	12 s	13 s
elevation	22 s	0,06	0,00	23 s	25 s
return	17 s	0,06	0,00	18 s	18 s
filling / silo displacement	16 s	0,06	0,00	17 s	17 s
fill cart in silo	12 s	0,06	0,00	13 s	13 s
silo / scale displacement	14 s	0,06	0,00	15 s	15 s
weighing	15 s	0,06	0,00	16 s	17 s
scale / filler displacement	11 s	0,06	0,00	12 s	13 s

e) Times of filler fill elements

Elements	Real-Time	Westinghouse System		Normal Time	Standard Time
		Skillful	Effort		
inlay	59 s	0,00	0,00	59 s	1:02 min.
time to seal	5 s	0,06	-0,04	5 s	6 s
inspection time	12 s	0,06	-0,04	12 s	13 s
weighing	20 s	0,06	-0,04	21 s	22 s
bagging	14 s	0,06	-0,04	15 s	15 s
stapling	5 s	0,06	-0,04	5 s	5 s
weighing 20kg packaging	11 s	0,06	-0,04	11 s	6 s

f) Times of inlay elements

Source: Field research (2015)

4.4 Productivity calculation

The deboning sector's productivity calculation was carried out for the activities involved in processing three main products: i) loin chop; ii) filet, and; iii) sawn rib.

As shown in Table 4, to produce the 5,5 kg rib sawn, six activities are required with a total ST of 1,7 minutes per piece, using nine workers in 15 days. For 1,03 kg fillet production, 6 activities are required, with approximately 1,98 minutes, using eight workers for 15 days. Eight activities are necessary to obtain the sawn rib of 2,27 kg, with a total ST of 1,92 minutes, using 11 workers in 15 days.

Table 5 and Figure 6 show a comparison of the productivity for May 2013 (observation period) for three products considered, which had their production volumes analyzed. Thus, there were several variations in productivity in this period, and there was also a particular day of work that did not produce a sawn rib. It can also be seen that the production process involving the fillet is the one that maintains the most significant irregularity. One possible cause of this irregularity is the high turnover of functions during the day, making employees with lesser skill in a specific function perform them, mainly because the company does not adopt an efficient production scheduling methodology.

With the determination of each product's daily productivity, it was possible to determine the monthly average productivity of the analyzed production processes, which are filet with 81%, loin chop with 74%, and a sawn rib with 73%.

Based on the evaluation parameter proposed by Toledo Jr. and Kuratomi (2004a), it is noticed that the productivity of the analyzed period had a regular behavior, being within the range of 71 to 90%. According to Toledo Jr. and Kuratomi (2004a), the selected productive processes fit in the range of up to 80%, which corresponds to organized industries and with productivity control.

Table 4: Production and productivity by-product (Deboning)

Production Volume (kg)	Quantity of pieces	Quantity of pieces (by worker)	ST (min.)	Working time (day)	Productivity (%)
1281,4	2306,56	256,28	1,7	435	100
9427,6	1698,67	188,74	1,7	434	74
11120,5	2003,69	222,63	1,7	392	97
4617,2	831,93	92,44	1,7	346	45
7137,7	1286,07	142,90	1,7	424	57
8839,34	1592,67	176,96	1,7	409	74
2738,4	493,41	54,82	1,7	164	57
5439,8	980,14	108,90	1,7	404	46
6365,9	1147,01	127,44	1,7	465	47
11097,5	1999,55	222,17	1,7	468	81
12189,22	2196,26	244,03	1,7	481	86
9969,98	1796,39	199,60	1,7	465	73
14081,55	2537,22	281,91	1,7	469	102
9892,02	1782,35	198,04	1,7	428	79
13808,19	2487,96	276,44	1,7	453	104

a) Loin chop

Concerning Tuscan sausage, five activities with five workers are required in the dough preparation process, and inlay requires seven activities and 25 workers are necessary. One box of sausage corresponds to 20 kg.

Production Volume (kg)	Quantity of pieces	Quantity of pieces (by worker)	ST. (min.)	Working time (day)	Productivity (%)
1600,16	1553,55	194,20	1,98	435	88
1460,54	1418	177,30	1,98	434	81
1520,21	1475,93	184,50	1,98	392	93
1040,61	1010,30	126,30	1,98	346	72
1419,79	1378,44	172,3	1,98	424	80
1220,41	1184,86	148,10	1,98	409	72
379,91	368,84	46,10	1,98	164	56
1299,40	1261,55	157,70	1,98	404	77
1619,18	1572,02	196,50	1,98	465	84
1579,48	1533,48	191,70	1,98	468	81
1739,34	1688,68	211,10	1,98	481	87
1638,95	1591,21	198,90	1,98	465	85
1679,55	1630,63	203,80	1,98	469	86
1419,86	1378,50	172,30	1,98	428	80
1659,39	1611,06	201,40	1,98	453	88

b) Filet

Production Volume (kg)	Quantity of pieces	Quantity of pieces (by worker)	ST (min.)	Working time (day)	Productivity (%)
4410,80	1943,08	176,60	1,92	435	78
6228,21	2743,70	249,40	1,92	434	110
4464,80	1966,87	178,80	1,92	392	88

Production Volume (kg)	Quantity of pieces	Quantity of pieces (by worker)	ST (min.)	Working time (day)	Productivity (%)
4447,22	1959,13	178,10	1,92	346	99
4571,33	2013,80	183,10	1,92	424	83
143,26	63,11	5,70	1,92	409	3
0	0	0	1,92	164	0
1458,23	642,39	58,40	1,92	404	28
4283,87	1887,17	171,60	1,92	465	71
4427,40	1950,40	177,30	1,92	468	73
5742,16	2529,59	230	1,92	481	92
2502,48	1102,41	100,20	1,92	465	41
4303,58	1895,85	172,40	1,92	469	71
5093,80	2243,96	204	1,92	428	92
3924,88	1729,02	157,2	1,92	453	67

c) Sawn rib

Source: Field research (2015)

Table 5: Production and productivity (by Tuscan sausage product)

Production Volume (kg)	Quantity of pieces	Quantity of pieces (by worker)	ST. (min.)	Working time (day)	Productivity (%)
23339,88	44,80	8,95	26,6	315	76
23419,01	44,95	8,99	26,6	450	53
23410,77	44,93	8,99	26,6	455	53
22108,76	42,43	8,49	26,6	460	49
4322,89	8,30	1,66	26,6	240	18
23463,37	45,03	9	26,6	454	53
23355,88	44,83	8,96	26,6	453	53
31474,46	60,41	12,08	26,6	460	70
13032,15	25,01	5	26,6	450	30
15714,96	30,16	6,03	26,6	345	47
6618,08	12,70	2,54	26,6	250	1527
23418,27	44,95	8,99	26,6	435	5455
23428,17	44,97	8,99	26,6	375	5464
34891,87	66,97	13,39	26,6	445	8180
23.431,51	44,97	8,99	26,6	455	5453
29.665,78	56,94	11,39	26,6	450	67
18.232,60	34,99	6,99	26,6	455	41
15096,89	28,98	5,79	26,6	465	33
17185,20	32,98	6,59	26,6	453	39
28650,71	54,99	10	26,6	445	66
30731, 90	58,99	11,80	26,6	450	70
17184,56	32,98	6,57	26,6	450	39

a) Dough preparation

Production Volume (kg)	Quantity of pieces	Quantity of pieces (by worker)	ST (min.)	Working time (day)	Productivity (%)
22442,74	1122,14	44,88	7,28	475	69
23158,67	1157,93	46,31	7,28	473	71
22465,46	1123,27	44,93	7,28	465	70
19288,83	964,44	38,58	7,28	473	59
11562,80	578,14	23,12	7,28	260	65
18688,13	934,41	37,38	7,28	475	57
19995,79	999.79	40	7,28	473	61
19660.09	983	39,32	7,28	473	62
21534,08	1076,40	43,07	7,28	480.5	67
16648,43	832,42	33,30	7,28	480.5	52
12249,13	612,45	24,50	7,28	465	71

Production Volume (kg)	Quantity of pieces	Quantity of pieces (by worker)	ST (min.)	Working time (day)	Productivity (%)
21874,21	1093,71	43,75	7,28	465	69
21150,04	1057,50	42,30	7,28	250	66
19994,81	999,74	39,99	7,28	463	62
22639,43	1131,97	45,28	7,28	470	70
20253,21	1012,66	40,50	7,28	467	63
17174,99	858,75	34,35	7,28	470	53
21218,22	1060,91	42,44	7,28	470	65
17366,39	868,32	34,73	7,28	470	54
22742,33	1137,12	45,48	7,28	473	70
12220,63	611,03	24,44	7,28	471	70
22233,36	1111,67	44,47	7,28	470	69
21231,44	1061,57	42,46	7,28	473	65
21781,09	1089,05	43,56	7,28	470	68

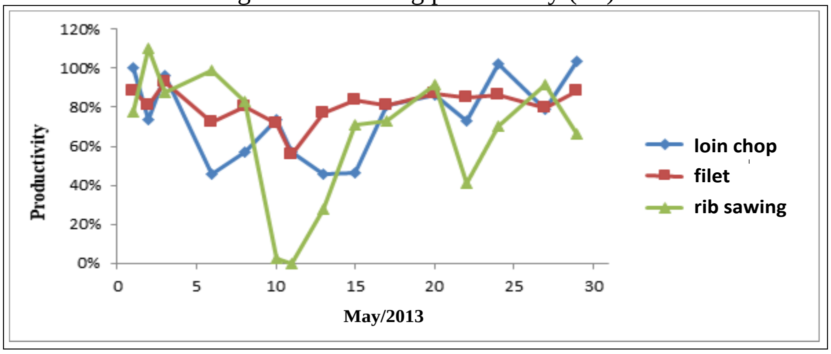
c) Inlay

Source: Field research (2015)

By analyzing Table 5a.) and Figure 7a.), it is observed that for the dough preparation process, regarding Tuscan sausage, there is no constancy in productivity and that at no time has it reached 100 %. According to April 2014, average productivity is equal to 50 %, demonstrating the employees' idleness, equipment, machines, and productive resources within the sector.

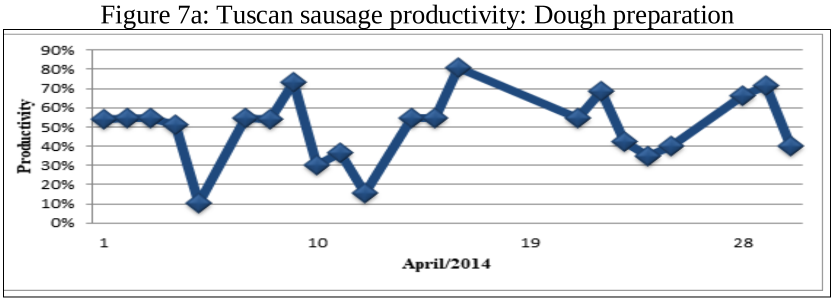
In the inlay sector (see Table 5b. and Figure 7b.), the average productivity of 65 % was observed for April 2014; also, it was observed some periods of constant productivity. According to Toledo Jr. and Kuratomi (2004a), the productivity of 50 % and 65 % demonstrates a "weak" industry, disorganized and without productivity control.

Figure 6: Deboning productivity (set)



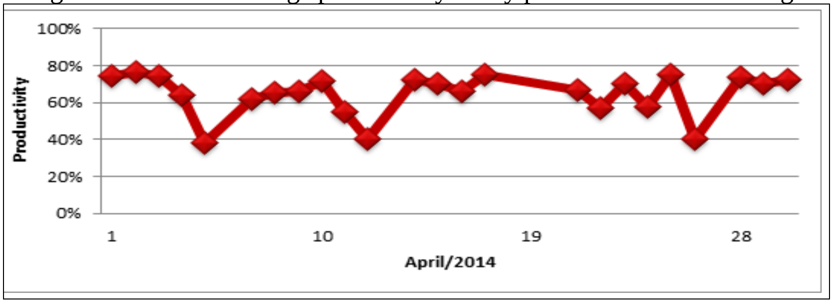
Source: Field research (2015)

Figure 7a: Tuscan sausage productivity: Dough preparation



Source: Field research (2015)

Figure 7b: Tuscan sausage productivity: Inlay process of Tuscan sausage



Source: Field research (2015)

4.5 Line balancing

To calculate the line balance (the average productivity for deboning and Tuscan sausage) and to obtain line balancing, it is necessary to calculate the number of balanced employees and then the balanced ST to execute activities.

In the dough preparation process, 2,85 workers are required (Table 6a.),i.e., three (Table 6b.), as shown in Figure 8. The number of employees in the inlay must be rounded up to the whole upper number, so 20 workers are needed.

Table 6: Parameters for balancing calculator on Tuscan sausage line

Total production (piece)	= 472.177,67
Average daily production (piece)	21462,62
Average daily in units (piece)	41,19
Process time (seconds)	1596
Time worked/day (seconds)	26400
Number of workers	2,85
Average daily production (piece)	21462,62
Average daily in units (piece)	41,19

a) Number of workers for dough preparation

Time process (seconds)	=1596
Number of Workers	3
ST Balanced (seconds)	532

b) ST balanced for dough preparation

Total production (piece)	=469.574,28
Average daily production (piece)	19565,59
Average daily in units (piece)	978,28
Process time (seconds)	437
Time worked / day (seconds)	26400
Number of workers	16,19
Average daily production (piece)	19565,59
Average daily in units (piece)	978,28

c) Number of workers for inlay

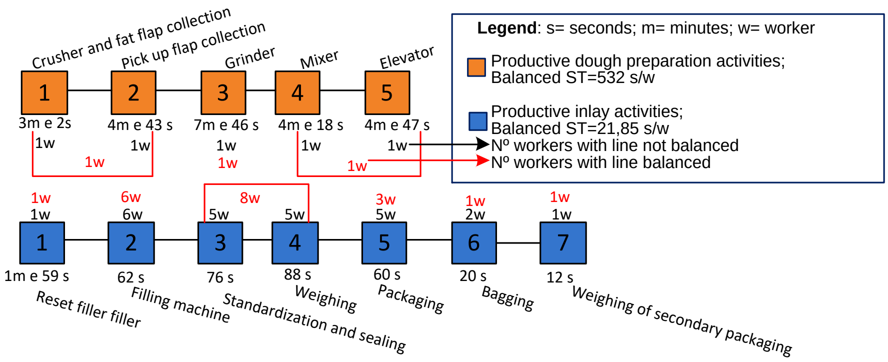
Time process (seconds)	= 437
Number of Workers	17
ST Balanced (seconds)	25,70

d) ST balanced for inlay

Source: Field research (2015)

Figure 8 shows a balanced line flow chart for the two processes of Tuscan sausage. According to the parameters of productivity and Standard-Times, the sector used five workers without the balance for the mass preparation process, minimizing to three after it was balanced. Regarding the inlay process, 25 workers were employed before and 20 after balancing. Balanced standard times should now be metrics for maintaining and improving productivity.

Figure 8: Balanced Tuscan sausage line



Source: Field research (2015)

In the deboning process, after the line is balanced, seven, seven, and nine workers are needed, respectively, for the loin chop, fillet, and sawn rib, according to Table 7.

Figure 9 shows the balanced line flowchart for three deboning processes. According to the parameters of productivity and Standard-Times, the sector used 28 workers without balance, minimizing to 23 after being balanced.

Table 7: Parameters for balancing calculation on deboning line

Products (kg)	Average daily production (kg)	Processes Times (s)	Time worked/day (s)
loin chop	9892,02	102	26040
fillet	1520,21	118,7	26040
rib sawing	4410,80	115,2	26040

a) Summary of data for balancing calculation

Products (kg)	Average daily production (kg)	Processes Times (s)	Time worked/day (s)
loin chop	1782,35	102	26040
fillet	7	118,7	26040
rib sawing	1475,93	118,7	26040

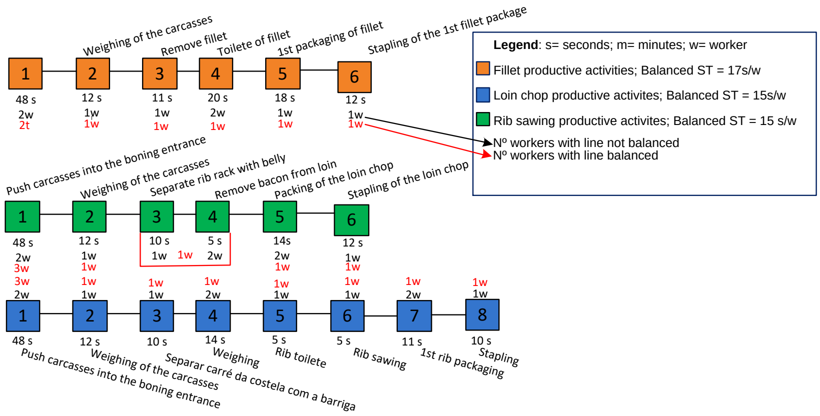
b) Determination of the number of workers

Products (kg)	Average daily production (kg)	Processes Times (s)	Time worked/day (s)
loin chop	102	7	15
fillet	118,7	7	17
rib sawing	115,2	9	13

c) ST balanced for deboning processes

Source: Field research (2015)

Figure 9: Balanced deboning production line



Source: Field research (2015)

5 CONCLUSIONS

The application of the Chrono-analysis tool in the present work identified standard-times in the Tuscan sausage and deboning sectors, which until then were absent in the literature, according to subsection 1.2. When preparing similar studies, many companies and professionals did not have studies or standard times to reference their operations and even to advance to the study of times and improvement of the performance of operations in swine slaughterhouses, however specific they may be to each company.

Also, of the Standard-Times' determination, other relevant results can be highlighted, such as the detailed flowcharts according to the time and type of operation. These flowcharts allowed, in the research, to specify the production lines and then balance them. These flowcharts can also provide the analyst with the study of layout, automation, replacement of equipment and financial engineering, readjustment of jobs, and safety engineering, among other aspects of analysis and decision.

The productivity analysis showed the average levels in which Industry X. In the deboning sector, there is fillet with an average of 81 %, loin chop with 74 %, and sawn rib with 73 %. As for the Tuscan sausage sector, productivity was 55 % for dough preparation and 60 % for inlay. There are possibilities for the improvement of productivity in both sectors.

Finally, line balancing is fundamental for optimizing resources involved in the production of the sectors analyzed, being a direct product of determining standard times, thus obtaining the balanced line with balanced standard times.

There was a 40 % reduction in labor resources in the Tuscan sausage sector through line balancing (five for two workers) with a balanced Standard Time of 532 seconds/worker. There was a reduction of 25 % (25 to 20 workers) with a balanced standard time of 21,85 seconds/worker in the inlay. In total, there was a reduction in this sector from 30 to 22 workers (a sectoral reduction of 23,33 %).

In the deboning sector, the reduction in the loin chop process was 22,22 % (nine for seven workers), in the fillet process, it was 12,5 % (eight for seven workers), in the sawn rib process, the reduction was 18,18 % (11 to nine workers). In total, there was a reduction in this sector from 28 to 23 workers (17,85 % sector reduction).

Our findings showed that classical and comprehensive knowledge techniques on Operations Management could bring performance gains. This scenario could be explained from the Practice-Based View lens when environmental characteristics and handling of internal assets are determinants for manufacturing improvements practices deployment and success. Productivity gains and cost savings observed in our study are the basement for both lower prices and reliability on food chains (immediate social benefits).

Future studies could explore the digital technologies' role on Times and Movies techniques. A plethora of disruptive technologies (augmented reality, Internet of things, big data, data analytics) linked to the Industry 4.0 concept have some degree of synergy with Times and Moves techniques. For continuous improvement, applying for Lean-Six Sigma programs after Chrono-analysis determination is a modern path for reaching competitive advantages; therefore, a few food industry literature studies explore this subject, which deserves attention in future research.

As research limitations, a case study refers only to specific industrial reality, limiting the generalizations about the findings, i.e., the findings serve only to build or expand theory based on restricting conditions of selected cases. Another limitation refers that the present study investigated only two sectors within the swine industry, limiting the overall evaluations at the unit level about the improvement benefits from Chrono-analysis use.

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APPENDIX A

Worksheet for Chrono-analyze (Industry X)

	WORKSHEET FOR STUDYING THE TIMES		Material Type:
Operation Description:			
Departament:	**Section :**	**Area/Sector:**	**Head Name :** / Date:
Study No.:	Previous Study No. :	Standard Time: **#DIV/0!**	Working Class :

DESCRIPTION						No.	01	02	03	04	05	06	07	08	09	10	Total Cycle	SCORES
						ELEMENTS												
SKILLFUL			EFFORT			01											-	
Superior	A1	+0,15	Excess	A1	+0,13	02											-	
	A2	+0,13		A2	+0,12	03											-	
Great	B1	+0,11	Great	B1	+0,10	04											-	
	B2	+0,08		B2	+0,08	05											-	
Good	C1	+0,06	Good	C1	+0,05	06											-	
	C2	+0,03		C2	+0,02	07											-	
Medium	D	1,00	Medium	D	1,00	08											-	
						09											-	
Regular	E1	- 0,05	Regular	E1	- 0,04	10											-	
	E2	- 0,10		E2	- 0,08	11											-	
Weak	F1	- 0,16	Weak	F1	- 0,12	12											-	
	F2	- 0,22		F2	- 0,17	13											-	
CONDITIONS			STABILITY			14												
Ideal		A1	Ideal			A	-	-	-	-	-	-	-	-	-	-		Total Time
Great		A2	Great			B												No. Observations
Good		B1	Good			C	-	-	-	-	-	-	-	-	-	-		Average Time
Medium		B2	Medium			D											#DIV/0!	Efficiency Factor
Regular		C1	Regular			E	-	-	-	-	-	-	-	-	-	-	#DIV/0!	Normalized Time
Bad		C2	Bad			F												% Fatigue
TIME							-	-	-	-	-	-	-	-	-	-	#DIV/0!	Normal Time+Tolerance
OPERATIONAL %			MACHINE %														1,00	Frequency
							-	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**#DIV/0!**	Standard Time
							Timekeeper's Visa: :				Head´sVisa :				Chronoanalyst´s Visa:			

Source: Field Research (2015)