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Defect Reduction by Total Quality Management in a Crackers Manufacturing System

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ABSTRACT

The main focus was to reduce defects in production lines of a newly started crackers manufacturing company as well as develop such a system so that mass defects can't happen again. To ensure a rated benefit & make the market value constant in the market an efficient system is one of the primary requirements. The prime qualities must be constant. So, to ensure that the causes of defects will not happen again the root-cause analysis has been done from the record of check sheet. Then all the errors from vital elements of production were detected and actual parameters, ingredient composition, temperature, pressure, steam supply etc. have been tried to maintain constantly. The co-operation of top to bottom hierarchy made this process successful & also able to build a permanent preventive system. Finally, a stable & reliable production system has been established to maintain target production and achieve maximum benefit ensuring excellent quality of product.

***Keywords*:** TQM, Check sheet, Fishbone diagram, Pareto analysis, Process flow chart, defect etc.

1. INTRODUCTION

In this hypothesis, the reduction of loss was the main concern. The basic tools of Total Quality Management have been used to record the amount the losses by observation on a daily basis in different shifts at different times. The total records were integrated to find an overall amount of loss. In order to develop a permanent solution, the roots of the problem

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were investigated. Interconnections of all elements & sub-elements of production were analyzed. All the departments and employees were involved to develop the total quality of products. Dirt particles in the production floor may be mixed with the ingredients or other open processes. Thus, contamination can occur and it will be caused by losing quality or market demand. So, even a cleaner is involved with the quality of a product. In this way, the roots of all defects or nonconformities have been determined. But, all the causes of defects can't be eliminated totally. Some can be reduced by a significant amount. Again, although zero defect in manufacturing is the target in actual practice, it is not possible to achieve zero defects. Because some causes of roots can't be eliminated permanently so, defects can't be eliminated permanently. If a machine runs for 30 days (suppose) it may fail at least 2 or 3 days. The failures may be failure or belt drive, broken sprocket, failure of small parts, downtime etc. So, it wise to reduce defects in a significant amount & prevent the causes to be happened again in further. Pareto analysis is a tool to determine the 'vital causes' which can be eliminated. So, the Pareto chart has been drawn.

To run a manufacturing system in order to meet the market demand a well-planned machine schedule, constant quality of ingredients, constant mixing ratio, actual pressure & temperature in particular process, continuous steam supply etc. have to be maintained accurately. A process flowchart is a smart representation of all process with standard symbols, ingredients etc. In case of any failure in production or to solve a new type of defect rapidly, it becomes easy to find the root or source of the defect from process flow chart. It increases the efficiency of a production system also.

After practicing the 4 tools of TQM in an order with safety & cleanliness issues strictly a satisfactory result has been achieved. The overall manufacturing process has come into full control which has been proved by 'c' control chart. Here, because it is a control chart of nonconformities under Poisson's assumption. In this manufacturing system, the process is continuous & one new cycle is starting after another after a certain interval when a full cycle is completed.

2. LITERATURE REVIEW

The food & beverage manufacturing company is a very profitable business in our country because of the large population. Crackers are very popular snacks with the teenagers and kids also. So, to achieve a good profit with comparatively small investment crackers industry can be chosen which may also reduce the risk of an investor. But this business is also very competitive. So, customer satisfaction & cost should be the prime factors to dominate the market. The main customers of crackers products are students and travelers. They always seek crackers which price is between 10-15 tk. Again, the flavor must be constant all time. The quantity (Ratio of air & crackers) is also a big factor in customer satisfaction. Finally, a continuous supply of product to the market according to demand must be maintained in order to retain the customers as well as the market for the product. So, to start a crackers industry these factors must be given more importance than others [1].

There is a proverb that "Prevention is better than cure". To start a business as well as an industry. This proverb must be obeyed to avoid losses. There are two major types of losses in manufacturing which are Abnormal Loss & Normal loss. The abnormal loss is also termed as the special loss. Special losses may happen sometimes but these can be eliminated also by

applying different techniques. But normal losses can't be eliminated. But it is possible to reduce them. These losses may increase the manufacturing cost which may also affect the quality of the product. So, to achieve the quality again some cost must be required which is termed as "The cost of Quality" [2]. Meanwhile, the customer may stop buying the product and market will be decreased also which will cause a great loss of business.

The special causes may not appear but the normal causes can be identified from the beginning. These may be the design of production floor, employees, manager, machines, and raw materials etc. From the planning stage, these all should be considered as involved with quality. In another word, we should apply Total Quality Management (TQM). Total Quality management concerns to develop such a system which ensures reduction or elimination the maximum causes of natural loss. It may be also called as preventive management.

In modern concept, it is strongly recommended that "make them right the first time". Emphasis is on defect prevention rather than on correction. It can also reduce the inspection cost as well as manufacturing cost. It also reduces the risk of losing market demand, quality cost, and other maintenance costs.

In fact, Total Quality management is a philosophy [3]. It refers to organization-wide effort to involve everyone to achieve & maintain quality. All the workers, Managers, higher authority, vendors are the part of TQM. All departments of an organization are connected to each other. All the workers are responsible to manufacture the desired quality product. The vendors or suppliers are responsible for quality also because if they provide low-quality raw material the product will be defected or will not meet the quality level. When breakdown occurs in a machine the manufacturing process is stopped and the product may not be supplied to the market at the right time. Again, if the environment of the production floor is not neat & clean then the products may be contaminated. So, a cleaner is also a part of quality. TQM will be the best method to reduce defects of the crackers industry at starting. If a product gains a good quality, it can achieve a very good demand in the market [4]. This will increase the probability of success in the business.

In the year 2001; T. Thiagaragan and M. Zairi implemented TQM in the Malaysian industrial context [5]. In the year 2010; G. K. Kanji, A. Malek & Bin A. Tambi showed how to apply Total quality management in UK higher education institutions [6]. In the year 2006; G. K. Kanji showed total quality management can help to achieve customer satisfaction with a lower cost [7]. In 2006; Ozden Bayazit & Birsen Karpak implemented TQM Turkish manufacturing industry to access the readiness of zero defect concept [8]. In 2009; S. M. Yusof & E. Aspinwall worked on Critical success factors for total quality management implementation in small and medium enterprises [9]. In 2010; G. S. Sureshchandar, C. Rajendran & R. N. Anantharaman build a Conceptual model for total quality management in service organizations [10].

3. MATERIALS AND METHODS

In order to convenience of research a local food & beverage company has been chosen as a model. The company manufactures 5 different types of products named 'Chicken Leg chips', 'French Fry chips', 'Coconut Crunch', 'Choco Ring', 'Chicken Wing chips', 'Tomatina Crunch'. There are seven basic tools of TQM [11]. Among all 4 tools are enough to determine, analyze and reduce the total loss. These tools are:

- Check Sheet
- Cause Effect Diagram
- Pareto Chart
- Process Flow Chart

By applying these tools one after another it can be can exactly get a desired result. The procedure is described below:

3. 1. Check Sheet

It is also known as 'Defect Concentration Diagram'. It is a structured sheet prepared in a software or manually record book. It may be called as a database of location of defects, causes of defects, frequency of defects also. Because, from a database, any record can be found easily. So, it is highly recommended to save all data in the Check Sheet electronically.
Procedures for preparing check sheet:

- Fix which product will be observes.
- Fix the time of observation.
- Set the duration of observation.
- Prepare the design of the form so that all required data can be recorded by making check marks.
- Perform verification & validation of the collected data.

Here is a possible model of a single Check sheet for collecting data of various parameters:

Table 1. Sample check sheet to record defects

Check Sheet		
Product name: Shift: Batch No.: Total defective pieces:	Product ID: Observation Time: M/C ID: Date:	
Type of Defect	**Frequency**	**Amount**

The mentioned defects are common for all crackers products of the corresponding factory. Data collected randomly, at different shifts, at different time, from different machines or processes, in different warehouses.

An overall observation of 20 days in crackers production line is given bellow:

Total Shifts: 2 Working Day: 5 days per week
Office hour: 8 am-6 pm

Table 2. Check sheet of Production line 1

Product name: Chicken Leg chips/ French Fry chips		Product ID:
Defect	**Frequency**	**Quantity**
1. Over Sheet thickness	28	1-2 mm
2. Shape deformation	33	2/3 per punch
3. Extra moisture contents	25	Lower temperature or pressure
4. Burnt pieces	40	30-40 per frying
5. Large variation of test	15	5-6 pieces per pack

The Production line for Chicken Leg chips & French Fry chips are same. There are 2 shifts in the factory 'Morning' & 'Day' shift. These 2 products are manufactured on the basis of demand forecasting from 'Supply Chain Dept.'. In our observation the mentioned defects in the check sheet have been found out. The full system is automatic & the whole product is produced without the touch of human hands.

Table 3. Check sheet of production line 2

Product name: Coconut Crunch/ Choco Ring		Product ID:
Defect	**Frequency**	**Quantity**
1. Excessive grain size	13	20-30%
2. Breakage	48	4/5 per extrusion
3. Irregular seasoning	20	30-35% per cycle
4. Extra Moisture content	14	5-8% extra
5. Shrinkage	09	50-70 pieces per bucket

Table 4. Check sheet of production line 3

Product Name: Chicken Wing chips/Tomatina Crunch		Product ID:
Defect	**Frequency**	**Quantity**
1. Extra moisture	11	6-8%

2. Shape deformation	26	4-5 per crushing
3. Test variation	24	8-12%
4. Burnt pieces	35	35-45 per frying

[N: B: The M/C ID, Product ID etc. are not permitted to disclose]

3. 2. Root Cause Analysis

Root cause analysis also called as 'fish bone' diagram as it looks like skeleton of fish. Kaoru Ishikawa developed it so it is also known as "Ishikawa Diagram" [12]. It is a very effective tool to find the root of any cause so that a permanent solution could be possible by elimination the roots of any problem. In this Industry the main sources or roots of defects and possible causes are shown in the "fish bone" diagram added below Figure 1.

3. 3. Pareto Chart

Famous Italian Economist Vilfredo Pareto stated that "about 80% of the country's wealth is occupied by about 20% of the population" [13]. It is also famous as '80-20' rule. The main concentration was wealth distribution in the society but this is now applied in various industrial applications such as materials grading, detect primary causes of defects etc. In Quality control it is proved that about 80% defects are occurred by 20% reasons. These 20% causes are known as 'Vital' causes. The vital causes of defects have been detected by applying Pareto 80-20 rule and from the check sheet & root cause analysis. The errors detected from the check-sheet of observation are mainly originated from the roots mentioned in the "fish bone" diagram. From the total observation of the Industry The 'vital causes' have been found. Ratings out of 100 have been distributed among the causes. The table added below shows the obtained result of total observation:

Table 5. Cause of defects rating table

Causes	Rating	Percent
Personnel	38	38%
Maintenance	21	21%
Machine	28	28%
Ingredient	4	4%
Environment	6	6%
process	3	3%
Total	100	100

[N: B: Ratings has been given on the basis of analysis of the sub-causes of root cause analysis]

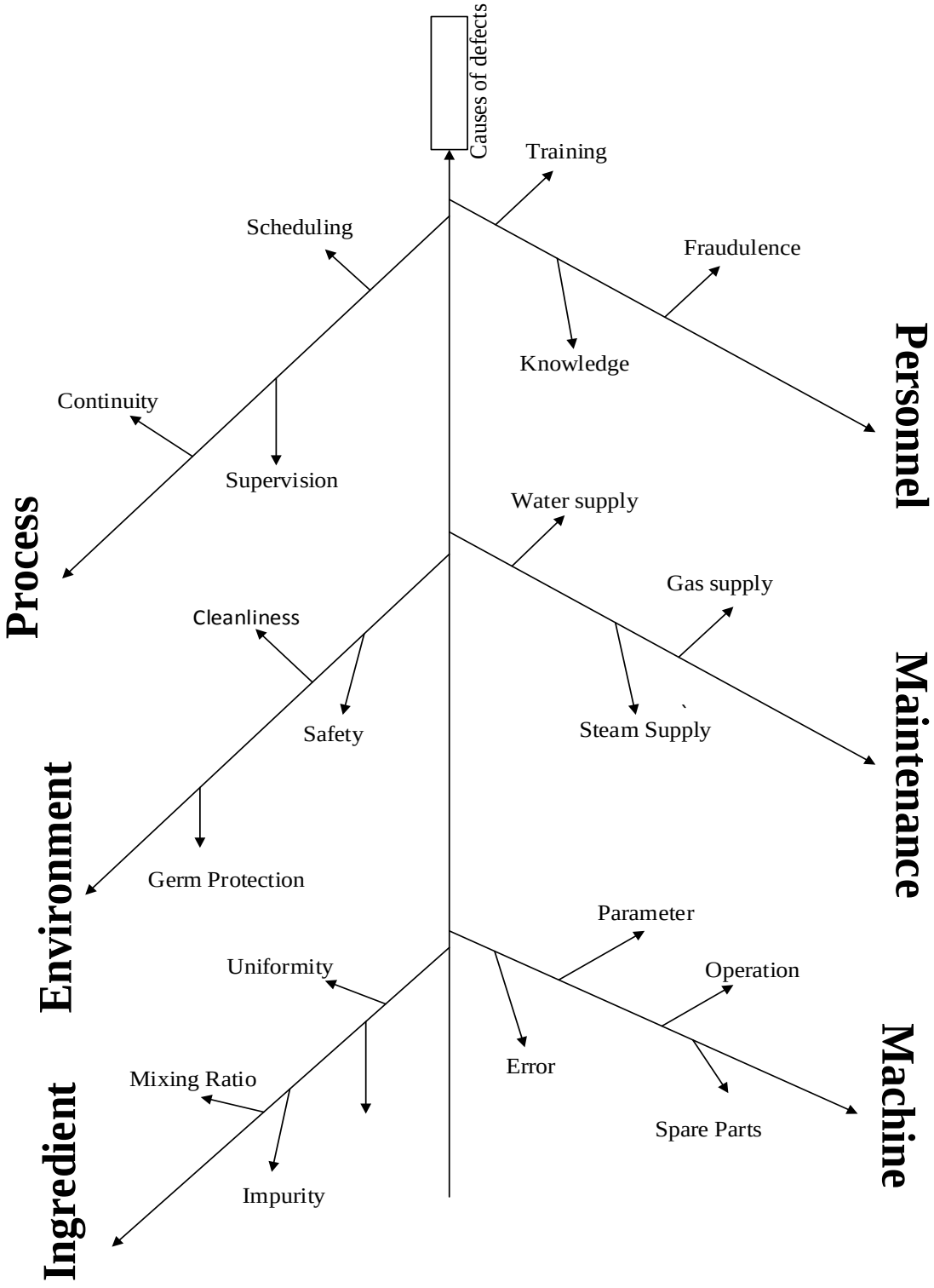

Figure 1. "Fish Bone" diagram for root cause analysis.

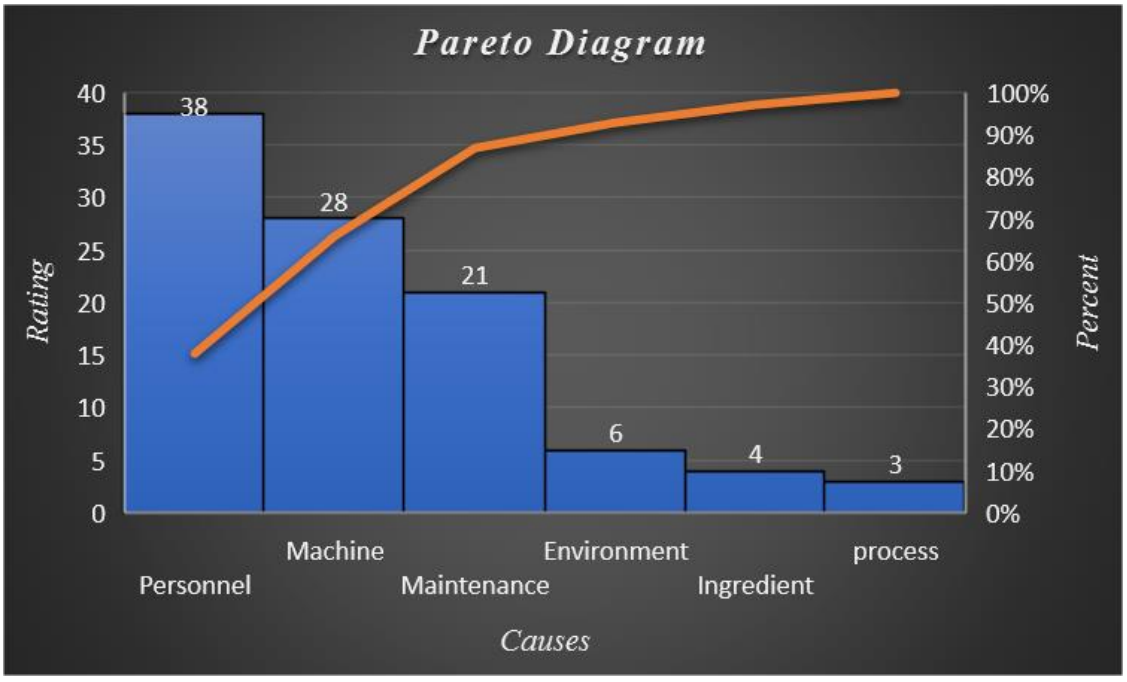

Figure 2. Pareto Diagram to determine 'Vital Causes'.

3. 4. Process Flow Chart

Process flow chart is a graphical representation to show steps in a process & how they are related to each other. It is also known as 'Run chart' or 'process map' [14]. By studying a process flow-chart, it is very easy to identify which step or steps are responsible for defects & what the cause of occurring defects there. So, it helps to develop an error-proof system. It is also a diagnosis tool & can be used to improve performance or effectiveness.

By considering the factory size and area of production floor the products have been designed in such a way that 2 types of product can be manufactured in a same production process as well as machine setup only by changing the ingredients. It saved a lot of place, machines, personnel as well as money for buying extra machines. In order to remove the root causes the parameters of pressure, temperature, dough sheet thickness, drying time etc. have been set up for particular process. The parameters are being maintained constantly. As a result, it was possible to eliminate the errors from 'vital causes'. By the elimination of vital errors, the minor causes automatically reduced significantly.

Detail schematic view of various product's process-flow charts are given bellow:

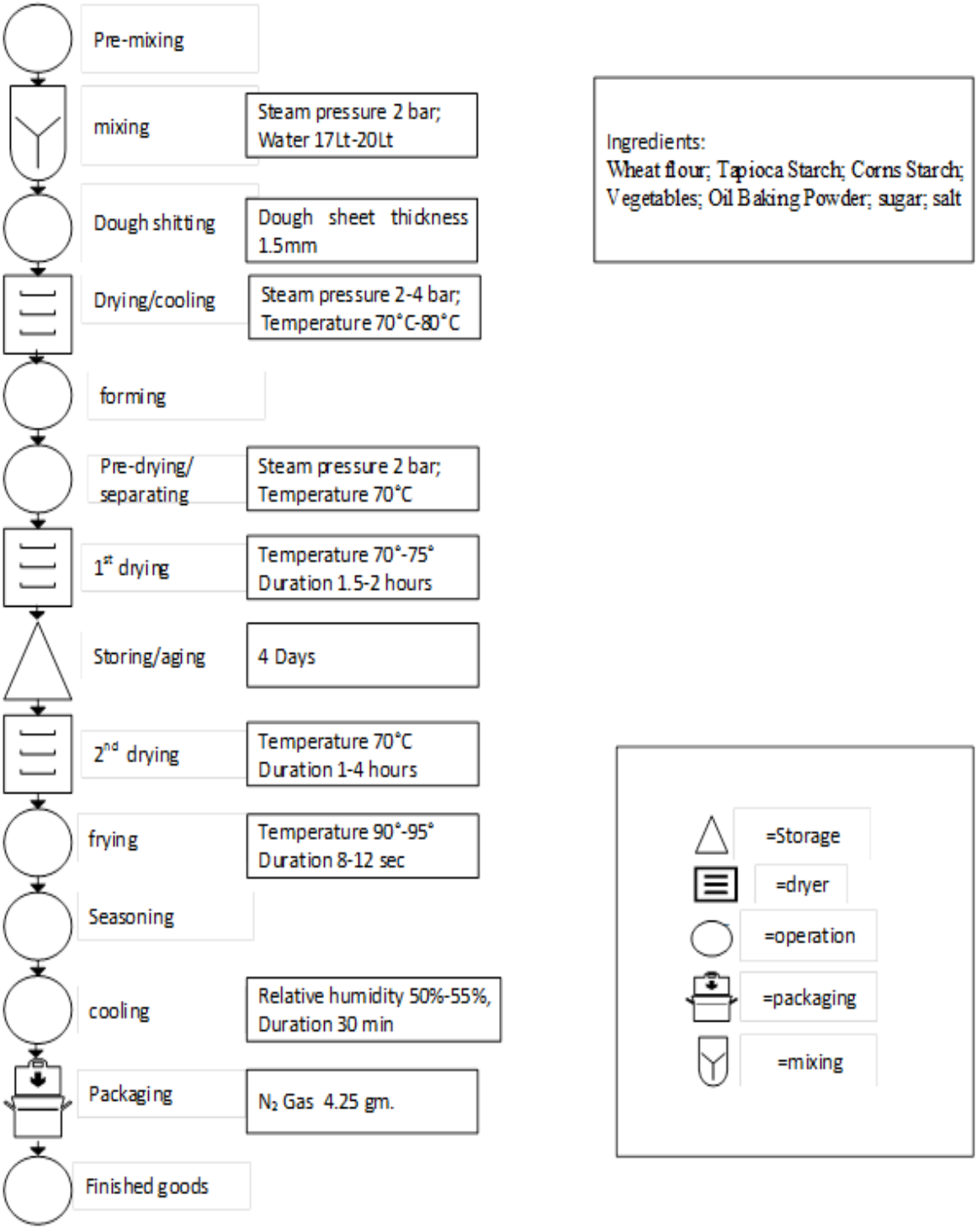

Figure 3. Process flow chart for 'Chicken Leg chips' Manufacturing.

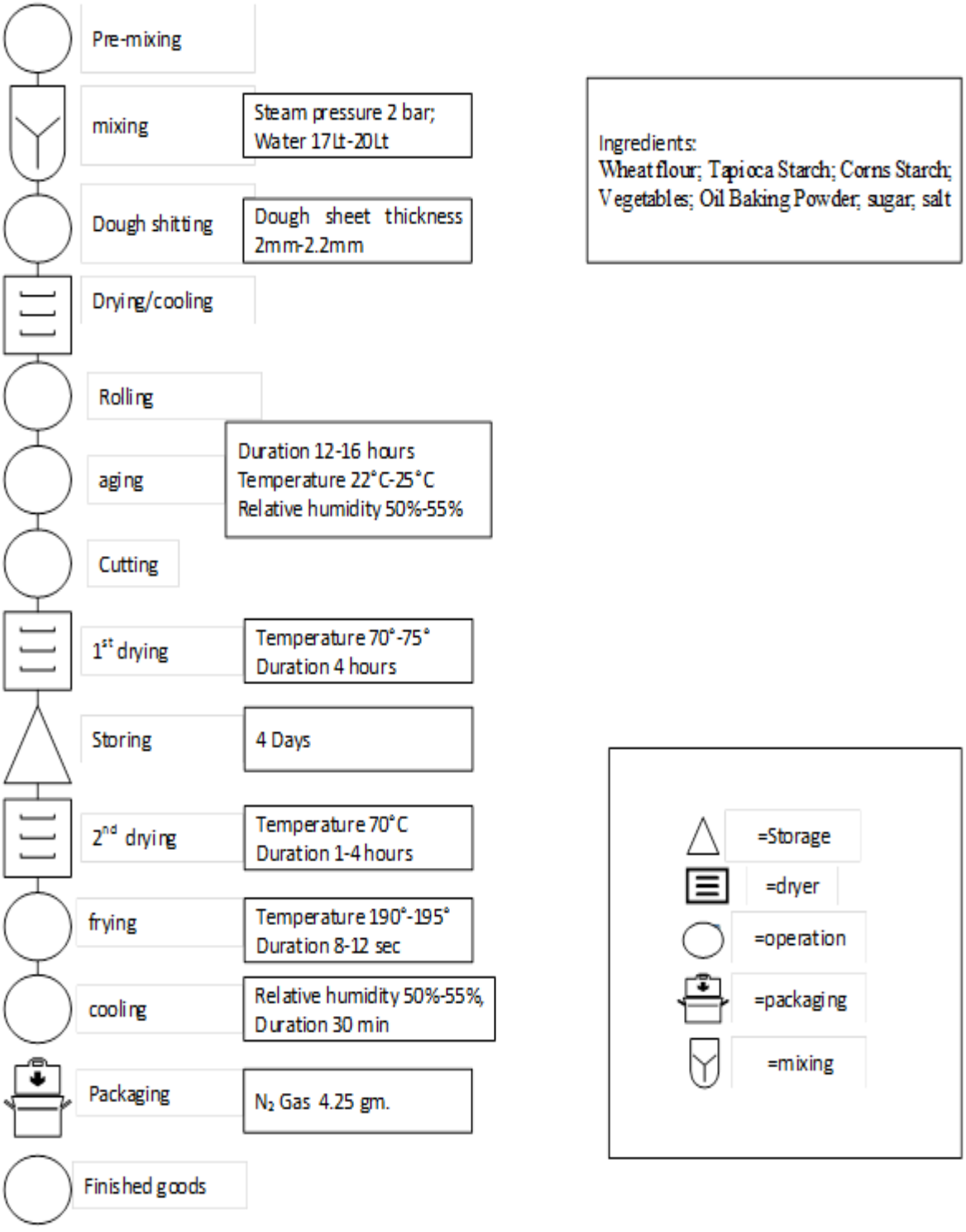

Figure 4. Process flow chart for 'French Fry chips' manufacturing.

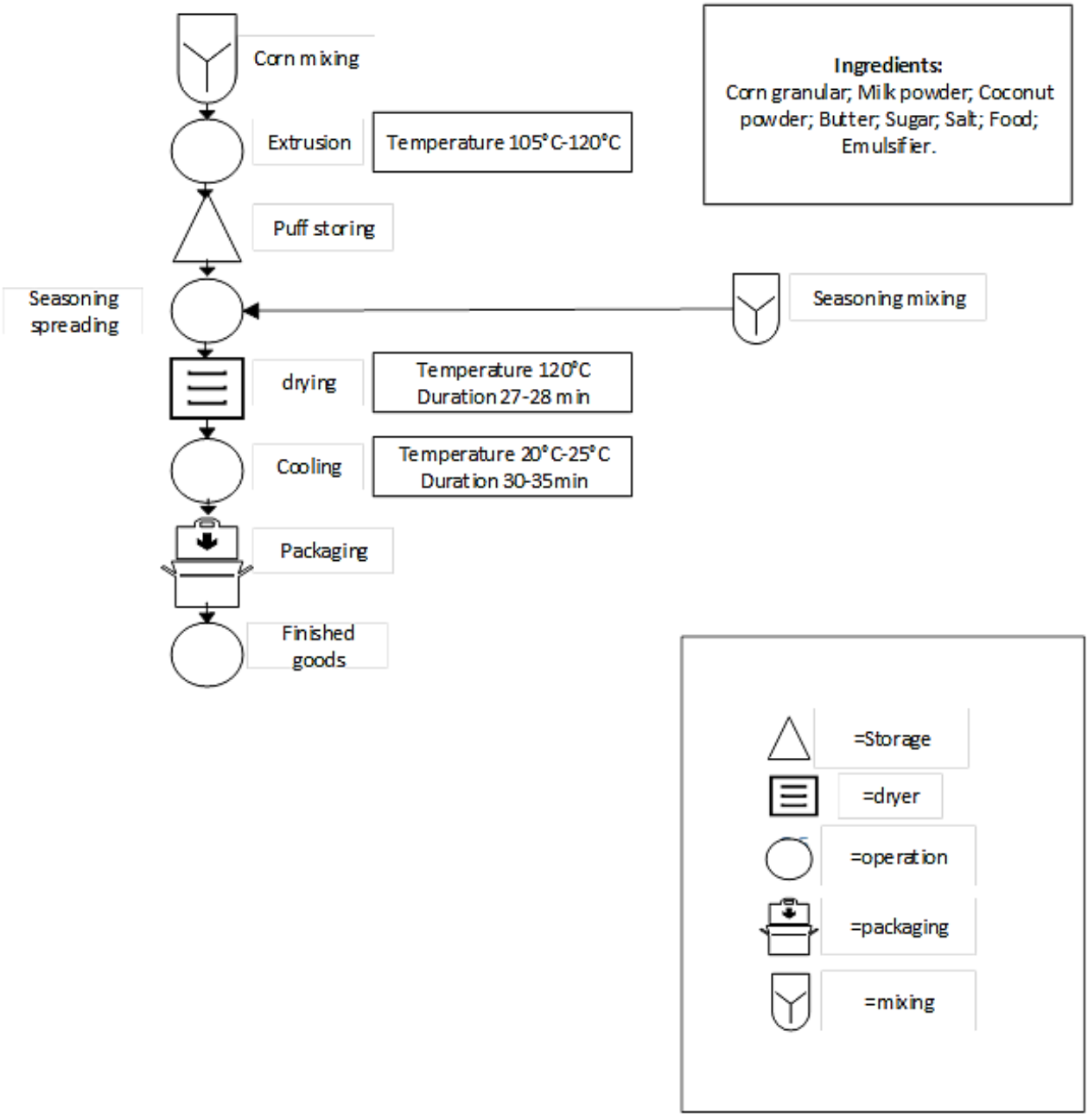

Figure 5. Process flow chart for 'Coconut Crunch' manufacturing.

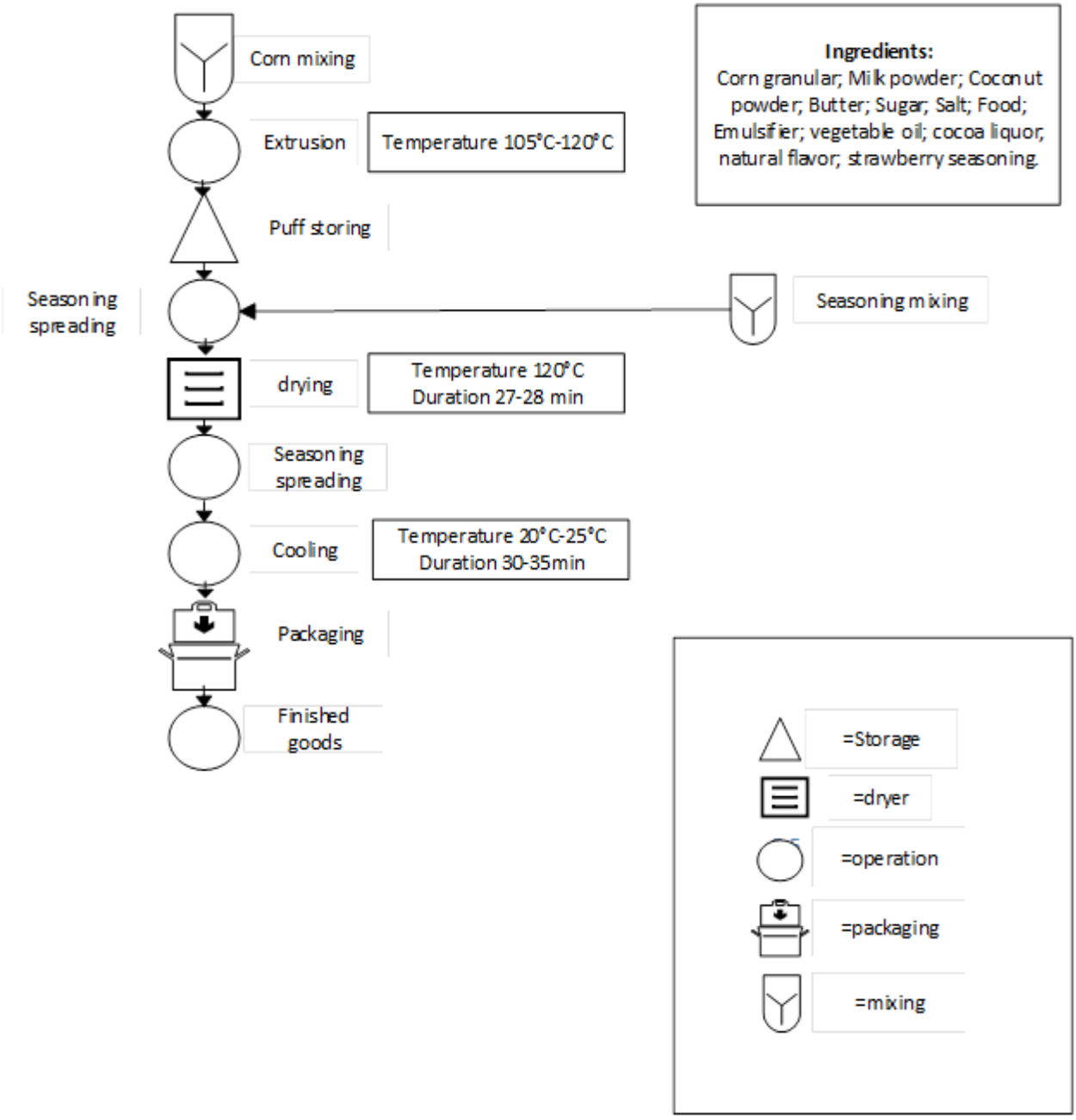

Figure 6. Process flow chart for 'Choco Ring' manufacturing.

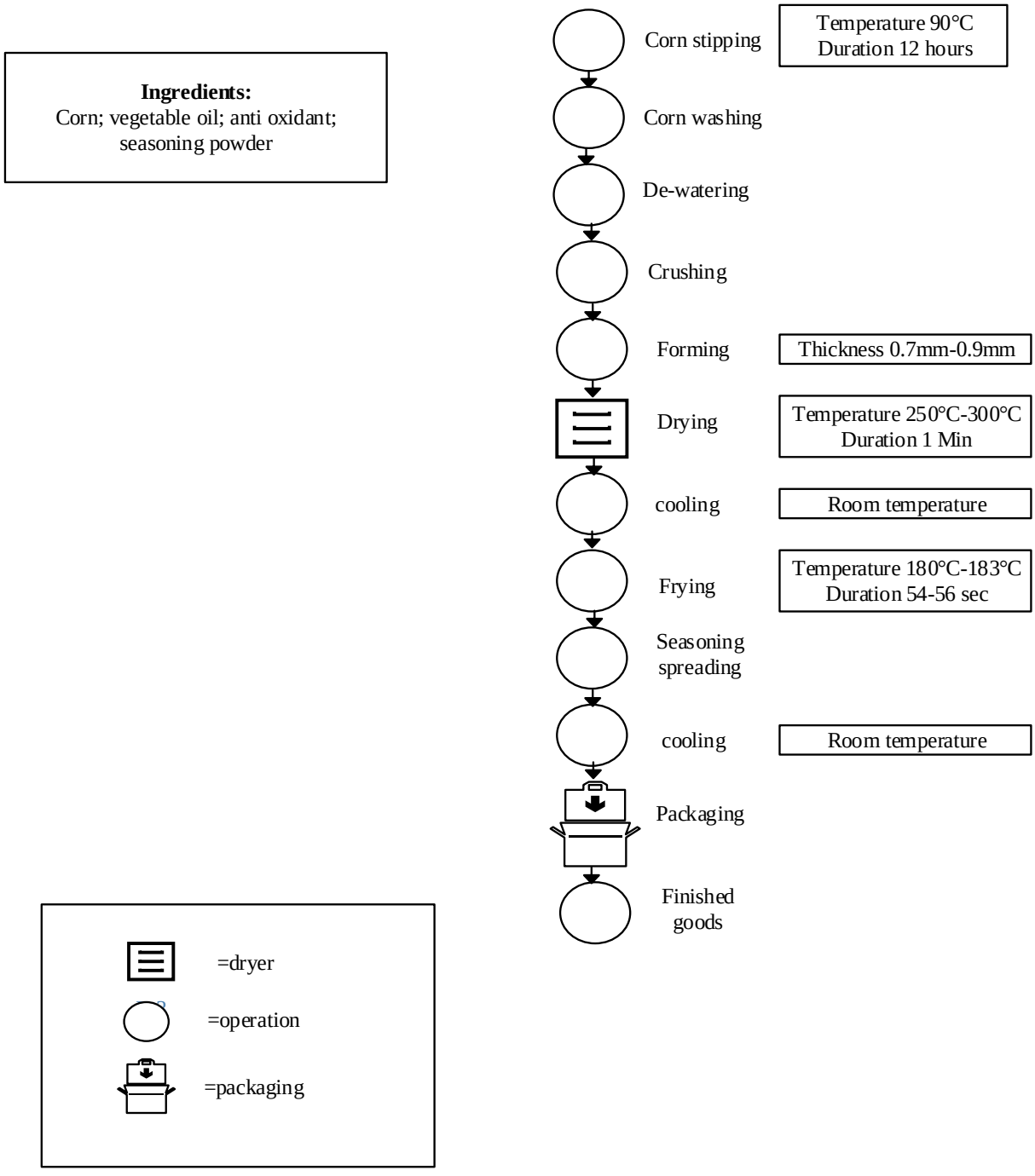

Figure 7. Process flow chart for 'Chicken Wing chips' manufacturing.

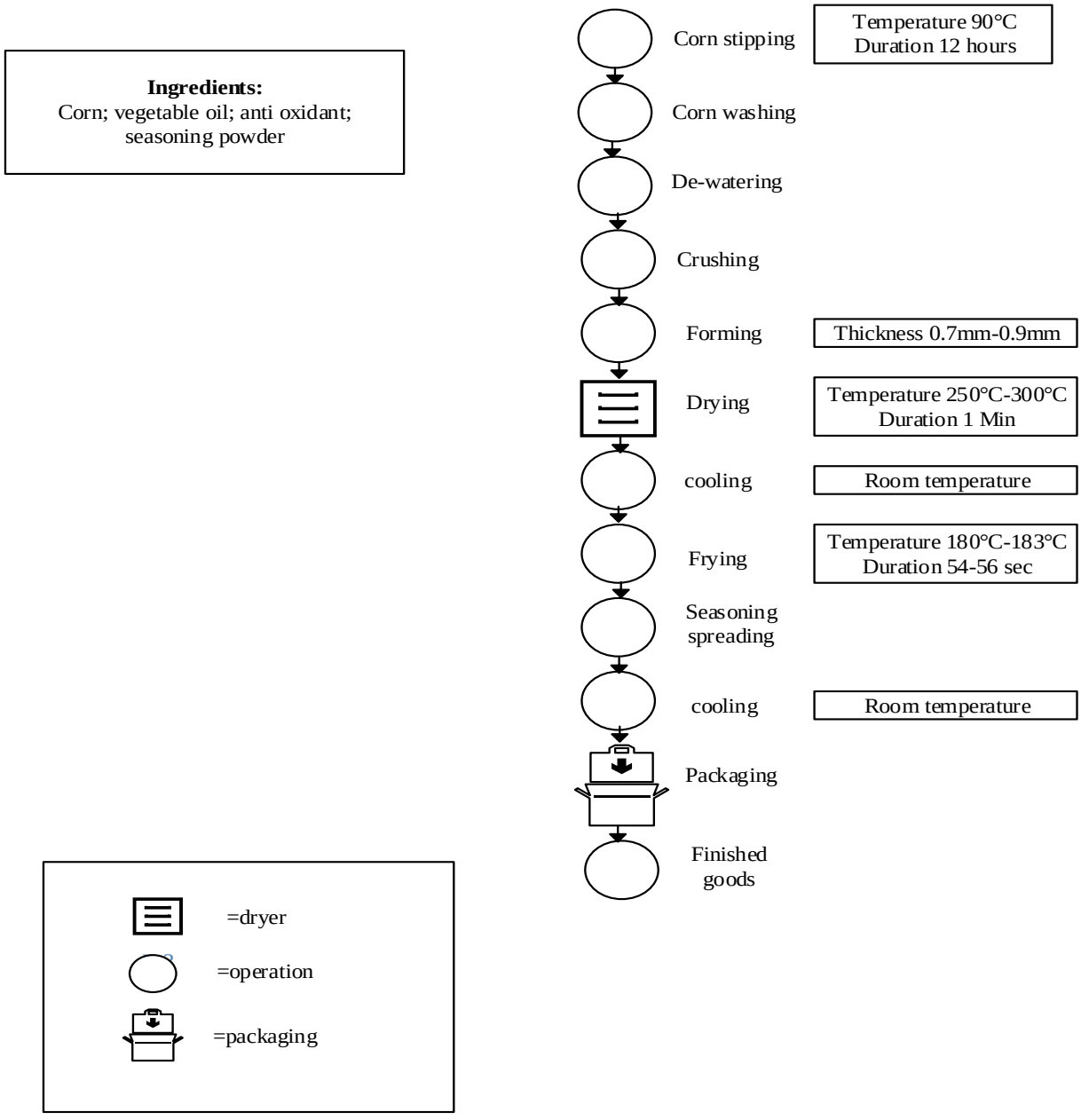

Figure 8. Process flow chart for 'Tomatina Crunch' manufacturing.

3. 5. Safety, Maintenance & Downtime management

To ensure the safety of the employee as well as the equipment safety is a main concern. Fire extinguishing system, Medical Team etc. are basic needs of an industry. There were managed enough spare parts to manage the downtime of machines. It has been mandatory to wear apron, hand gloves & head covering etc. to ensure the hygiene. No external contamination is allowed in the production floor.

4. RESULT

After suggesting this methodology, the Manufacturing board of the Industry was truly impressed & they also made analysis of the whole methodology. They also found this methodology as very efficient & applied for a trial basis for one month. Then they send the result with warm thanks. The following tables are given bellow:

Table 6. Frequency of defect comparison table of production line 1

Chicken Leg chips/ French Fry chips production line		
Defect	**Frequency**	
	Before	After
Over sheet thickness	28	09
Shape deformation	33	12
Extra moisture content	25	05
Burnt pieces	40	11
Large variation of test	15	04

Table 7. Frequency of defect comparison table of production line 2

Coconut Crunch/Choco Ring production line		
Defect	**Frequency**	
	Before	After
Excessive grain size	13	02
Breakage	38	09
Irregular seasoning	20	05
Extra moisture content	14	01
Shrinkage	09	02

Table 8. Frequency of defect comparison table of production line 3

Chicken Wing chips/Tomatina Crunch production line		
Defects	**Frequency**	
	Before	After
Extra moisture	11	02
Shape deformation	26	06
Test variation	24	04
Burnt pieces	35	09

The mathematical formulas to determine the reduction of overall defects are given bellow:

Defect reduction for each criterion

$$d = 100 - \frac{Before - After}{Before} \times 100\% \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (i)$$

Total defect reduction for each production line

$$d_t = \frac{\sum d}{\sum n_d} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (ii)$$

$$n_d = no.of\ defects\ in\ each\ production\ line$$

Overall defect reduction

$$D_{overall} = \frac{\sum d_t}{\sum n_l} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (iii)$$

$$n_l = no.of\ production\ lines$$

The final output from the formulas are given bellow:

Table 9. Reduction of total and overall defects table

No. of Line	Name of the production line	Total reduction of defect
1	Chicken Leg chips & French Fry chips	28.532%
2	Coconut Crunch & Choco Ring	18.207%
3	Chicken Wing chips & Tomatina Crunch	20.9075%
Overall		22.707% ≅ **23%**

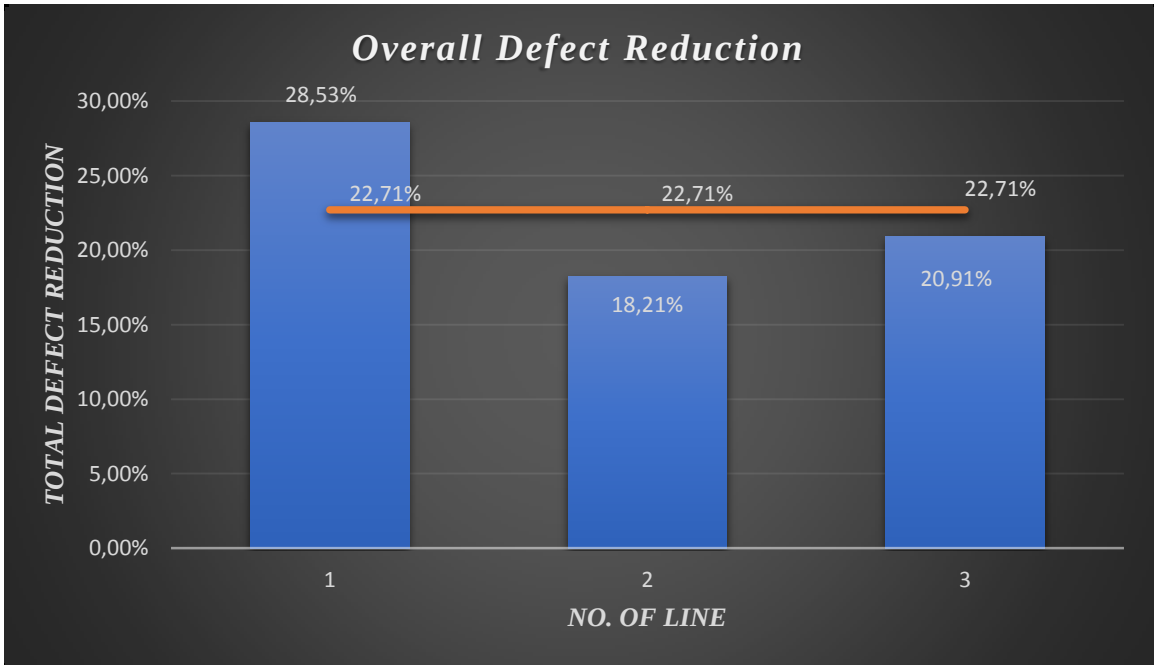

Figure 9. Overall defect reduction diagram.

After applying the 4 tools of Total Quality Management (TQM) a significant reduction of overall defects has been achieved. This increased the total benefit of the Industry & also helped to build an efficient system permanently.

Control Charts: Defects can be termed as nonconformities in quality control also. "The c chart is an attribute control chart for number of nonconformities". The control charts of before and after applying this methodology will easily help to notice a significant change in the overall manufacturing system [15].

Table 10. Number of nonconformities before

Serial No.	Frequency of failures/ Nonconformities
1	28
2	33
3	25
4	40
5	15
6	13
7	38
8	20
9	14
10	09
11	11
12	26
13	24
14	35
	Total = 331

Mean no. of nonconformities:

$$\bar{c} = \frac{331}{14} = 23.64$$

Control limits before:

$$UCL = \bar{c} + 3\sqrt{\bar{c}} = 38.226$$

$$LCL = \bar{c} - 3\sqrt{\bar{c}} = 9.05$$

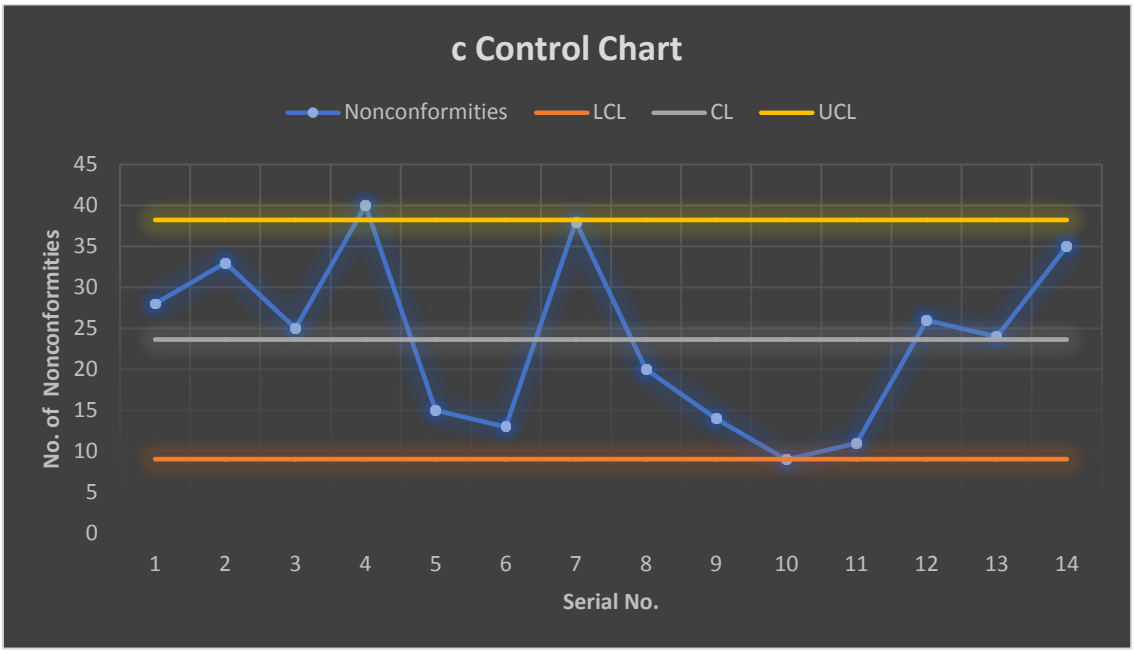

Figure 10. c control chart of crackers manufacturing before methodology.

Table 11. Number of nonconformities after

Serial No.	Frequency of failures/ Nonconformities
1	09
2	12
3	05
4	11
5	04
6	02
7	09
8	05
9	01
10	02
11	02
12	06

13	04
14	09
	Total = 81

Mean no. of nonconformities:

$$\bar{c} = \frac{81}{14} = 5.8 \approx 6$$

Control limits after:

$$UCL = \bar{c} + 3\sqrt{\bar{c}} = 13.35$$

$$LCL = \bar{c} - 3\sqrt{\bar{c}} = -1.35$$

$$LCL = 0$$

[N.B. LCL is taken 0 when it is negative in actual calculation]

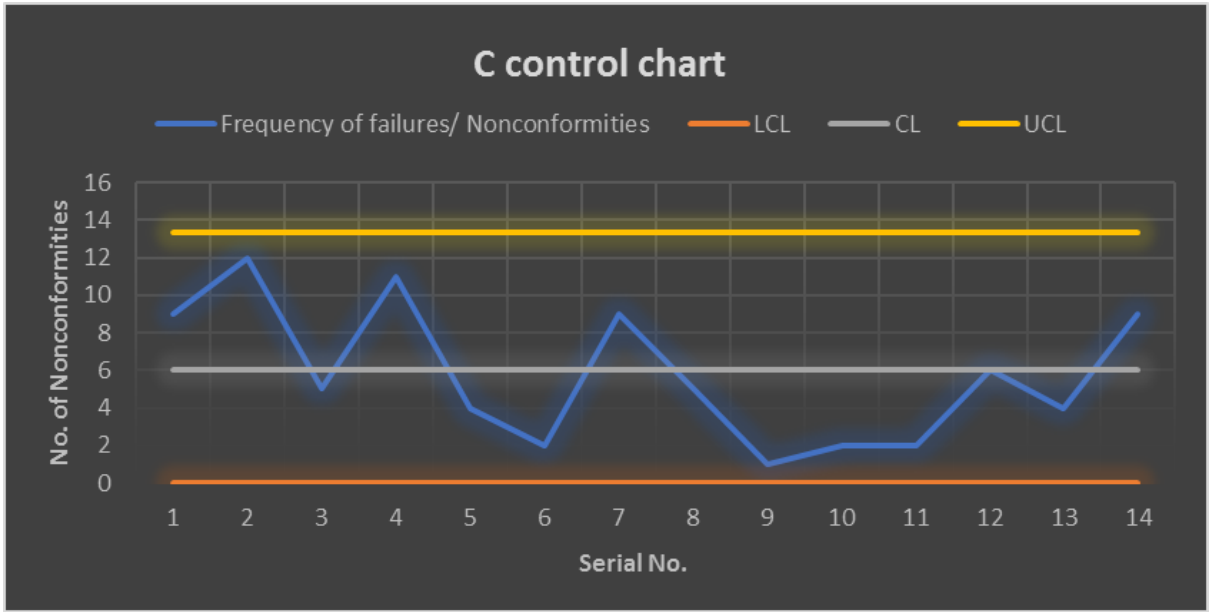

Figure 11. c control chart of crackers manufacturing after methodology.

3. CONCLUSIONS

TQM method is very suitable to develop efficiency of a small system or to reduce defects as well as losses. For a better result in larger systems it should be applied for a long

time involving all employees. If it is not possible to involve all employees, then the actual achievement thorough TQM is not possible. Also, it is sustainable & long lasting preventive method because there are very little chances of defects as the roots of defects are eliminated. Although, we consider or assume zero defect in a production system but in actual practice it is not possible to achieve zero defect only applying TQM. But, obviously TQM can prevent most of the defects to happen again.

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