CHAPTER 3

QUALITY ASPECTS OF TEA AND TOTAL FAILURE MODE AND EFFECTS ANALYSIS: A THEORETICAL TREATISE

3.1 INTRODUCTION

After the results of the literature survey suggested the conduct of investigations on implementing TFMEA in the tea industry, a deeper study of the quality aspects of the black tea was required to be carried out. Subsequently the parameters that determine the quality of tea were studied. The information gathered from these studies is presented in the next section. Besides these studies, a procedure for implementing TFMEA in the tea industry was designed. The details of these works along with the information gathered are presented in this chapter. In order to delineate the application of implementing the procedure on TFMEA technique in the tea industry, a hypothetical case study is illustrated in this chapter.

3.2 QUALITY ASPECTS OF TEA

Any product is evaluated on the basis of its quality (Montgomery 2010). In the same way, tea is also evaluated on the basis of its quality. The quality of tea is first evaluated in the factory by the tea maker. The tea maker evaluates the quality of tea manufactured in the factory in order to ensure that the tea that leaves the factory is of uniform quality and free from defects. In addition to this kind of evaluation, the quality of tea and its value are evaluated by commercial tea tasters. These tea tasters carry out tea tasting exercise. Tea tasting is aimed at identifying the defects and evaluating the different grades of tea that are to be marketed. The common defects identified and quality parameters evaluated during the tea tasting
are briefly discussed in the following subsections (Sarma, 2000; Food and Agriculture Organization of the United Nations, 1988; Krishna Vigyan Kendra, 1999).

3.2.1 Common defects and quality parameters of tea

Some common defects that affect the quality of tea are case hardening, stewing, bitterness, flakiness, excessive stalk and fiber, non-uniform size of tea particles, thin liquor, no briskness, greenness, smoke smell of tea and over burnt tea. Case hardening, over burnt tea and bitterness occurs when the tea is subjected to excessive firing.

3.2.2 Appearance

Appearance of tea is judged by the color of the particles, presence of stalk and fiber and the twist of the tea. The common defects in appearance are flakiness, excessive stalk and fiber, loss of bloom, non-uniform size of particles and greenness. These defects are caused due to coarse plucking, poor withering, improper rolling, and over or bad sorting.

3.2.3 Color

Color refers to the color of the tea liquor (tea liquor is formed when tea powder is dropped in hot water). Bright red is considered to be the best color. Green or brown liquor is considered defective. These colors result from under and over-fermentation. Green liquor, especially, may develop from under-rolled leaf.

3.2.4 Strength

Strength is the characteristic which denotes a concentration of substances that contributes to the taste of tea. The common defect in this characteristic is softness, which occurs due to over-fermentation or existence of excessive moisture in the tea particles. Stewing and case hardening may also cause softness.
3.2.5 Pungency

Pungency refers to the tea liquor without bitterness, but with astringency. Pungency is not attainable at all times, since the climatic conditions that create it in tea shoots occur only during certain periods of the year. However, too much pungency can lead to the common defect called ‘bitterness’.

3.2.6 Case hardening

During drying, the rate of moisture removal from the fermented leaf should be maintained between 3.2 to 3.5% per minute. When the rate of moisture removal is above the optimum and core moisture is not removed properly, tea gets case hardened. If firing is carried out with due care, the moisture on the surface of the leaf and that which stays inside the solid particles is diffused and evaporated. If the temperature of firing is very high and the rate of loss of moisture is too rapid, the surface of the particles may dry out and a hard crust may be formed, leaving moisture in the core of the particles. The effects of case hardening are listed below:

- Case hardening makes the tea liquor thin and bitter.
- Owing to the extra moisture that stays within the particles, the tea cannot be preserved for a long time, although the tea may appear to be well dried.
- During a period of time, the hard outer skin of case hardened particles begins to show small cracks (blisters) which give the tea a greenish color.

3.2.7 Flavor

Flavor refers to a marked flowery smell together with other tea aromas. Normally, this characteristic is available in tea manufactured from tea shoots grown in high elevation tea fields. These tea shoots are plucked from tea plants which originate from China and certain hybrid types.
3.2.8 Infusion

In tea tasting, the term “infusion” refers to the wet tea left-over after the tea liquor is produced. Tea liquor is produced by soaking dry tea in boiling water. Bright and even infusion is considered valuable. Common defects in infusion include unevenness, dullness and greenness. Unevenness is caused by bad sorting. Dullness is caused due to over-fermentation, whereas greenness is caused due to insufficient fermentation and rolling.

Major defects and the values of the factors that cause them are described in the above subsections. Besides the values of many other minor factors and many minor parameters like humidity, ambient temperature of air, climatic conditions etc. also determine the quality of tea manufactured. It has been a challenging task for the tea manufacturers to identify optimal values for these factors which facilitate the manufacturing of high quality tea. The optimal values for these factors can be determined by employing techniques like TFMEA.

3.3 HYPOTHETICAL CASE STUDY

As mentioned earlier, during the second stage of the doctoral work being reported here, a procedure for implementing TFMEA in the tea industry was designed. The steps of this procedure are illustrated in this section by presenting a hypothetical case study. In this hypothetical case study, a tea company is considered to be situated in Nilgiris district of India. This company’s name is assumed to be ABC. Tea manufactured from tea plants grown in the high elevation fields in the Nilgiris are known for its very good flavor. Nilgiris is a hill district with three major towns and several villages.

ABC was started in the year 1950. Currently 200 employees are working in the ABC. Out of them, 175 are laborers involved in plucking tea leaves and processing them. Remaining employees are occupying managerial positions. ABC
faces tough competition in the global market. The management of ABC has realized that improving quality of tea and its manufacturing process is imperative to face the global competition. In this regard, an engineer exposed to TQM practices is consulted. After studying the production practices, the engineer suggests the implementation of TFMEA for overcoming the defects encountered in the manufacturing of tea at ABC. Hence ABC management appoints the engineer as TFMEA programme coordinator. Considering the factors like production volume, employee strength and lack of awareness about continuous quality improvement techniques, the engineer proposes the time plan for implementing one cycle of TFMEA programme. The time plan is shown in Table 3.1. As shown, the engineer proposes to carry out 13 steps to implement the TFMEA technique in ABC in 60 days.

**Table 3.1 Steps and time plan proposed for implementing the TFMEA technique**

<table>
<thead>
<tr>
<th>Step number</th>
<th>Title of the step</th>
<th>Time plan</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Starting day</td>
</tr>
<tr>
<td>I</td>
<td>Exposing TFMEA programme to the management</td>
<td>1</td>
</tr>
<tr>
<td>II</td>
<td>First joint meeting with managerial employees and laborers on TFMEA programme</td>
<td>2</td>
</tr>
<tr>
<td>III</td>
<td>Second joint meeting with managerial employees and laborers on the conduct of TFMEA programme</td>
<td>3</td>
</tr>
<tr>
<td>IV</td>
<td>Discussion with managerial employees about laborer’s interest towards TFMEA programme</td>
<td>4</td>
</tr>
<tr>
<td>V</td>
<td>Invitation of laborers to become members of TFMEA team</td>
<td>5</td>
</tr>
<tr>
<td>VI</td>
<td>Formation of TFMEA team</td>
<td>6</td>
</tr>
<tr>
<td>VII</td>
<td>First meeting of TFMEA team</td>
<td>7</td>
</tr>
<tr>
<td>VIII</td>
<td>Conduct of first brainstorming session and development of TFMEA tables</td>
<td>8</td>
</tr>
</tbody>
</table>
The activities carried out at ABC under these 13 steps are briefly described below.

**Step I: Exposing TFMEA to the management**

The engineer discusses with the managerial personnel of ABC about the essence of TFMEA programme and lists its capability in improving the quality of tea produced and that of the process employed. The managerial personnel acquire sufficient knowledge about the TFMEA programme. As TFMEA is a simple technique, it instigates interest among the managerial personnel to involve in the TFMEA programme of ABC.

**Step II: First joint meeting with managerial employees and laborers on TFMEA**

The engineer convenes a joint meeting of managerial employees and laborers of ABC. The engineer explains about the need of improving the quality of tea to face the global competition. The engineer also explains about the danger of not ensuring quality of tea and its processes in the current competitive scenario. The engineer suggests another date in which he will deliver more details about achieving high degree of quality in the tea manufacturing using TFMEA technique.
Step III: Second joint meeting with managerial employees and laborers on the conduct of TFMEA programme

The engineer convenes the second meeting of managerial employees and laborers. In this meeting, the engineer explains about the TFMEA technique using simple language. The engineer requests the audience of this meeting to initiate TFMEA programme at ABC by listing the defects affecting the quality of tea manufactured in ABC. After the exhaustive list of defects is prepared, the engineer welcomes the audience to choose the most important defect that should be overcome through the conduct of TFMEA programme at ABC. In response to this call, the audience chooses ‘case hardening’ as the defect to be overcome in the processing of tea at ABC.

Step IV: Discussion with managerial employees about laborers’ interest towards TFMEA programme

The engineer discusses with the managerial employees about the interest shown by the laborers towards supporting the TFMEA programme. These managerial employees approve the selection of ‘case hardening’ defect to be overcome through the implementation of the TFMEA programme.

Step V: Invitation of laborers to become members of TFMEA team

The engineer approaches the laborers in groups and invites them to join as TFMEA team members for evolving solutions to overcome case hardening defect in the manufacturing of tea at ABC. The engineer notes down the names of laborers willing to join as the TFMEA team members.

Step VI: Formation of TFMEA team

The engineer presents the list containing the names of laborers who are willing to be the members of TFMEA team. Ten of the managerial employees are now included as TFMEA team members. The managerial personnel also approve
the selection of ten laborers as the TFMEA team members. Thus the TFMEA team with equal participation of managerial employees and laborers is built at ABC.

**Step VII: First meeting of TFMEA team**

The engineer convenes the first meeting of TFMEA team. In this meeting, the engineer explains about brainstorming technique. Particularly, the engineer emphasizes the rules to be followed while participating in brainstorming sessions. During this meeting, it was decided to develop TFMEA tables pertaining to three sections of ABC namely production, electrical and quality control. It is found that TFMEA team members are represented from each of these sections.

**Step VIII: Conduct of first brainstorming session and development of TFMEA tables**

The engineer convenes the first brainstorming session to identify the primary cause of ‘case hardening’. After thorough deliberations, improper maintenance of temperature is identified as the cause. In the same meeting, the degree of importance attached to each section is determined. Subsequently TFMEA tables are developed by the TFMEA team members. The hypothetical TFMEA tables developed are shown in Tables 3.2 – 3.4. In this table, the TFMEA members also indicate the ratings and recommended actions.

**Step IX: Approval of TFMEA tables by the top management**

The engineer submits the TFMEA tables to the top management. The top management approves and agrees to implement the recommended actions.
### Table 3.2. TFMEA – Production Engineering

<table>
<thead>
<tr>
<th>TFMEA number</th>
<th>Failure Mode</th>
<th>Cause of failure</th>
<th>Effects of failure</th>
<th>Present control</th>
<th>Rating</th>
<th>Departments</th>
<th>Recommended activities</th>
<th>Approved by</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Case hardening</td>
<td>Over heating of tea</td>
<td>Burnt taste of tea</td>
<td>Manual control using thermometers</td>
<td>8</td>
<td>Electrical engineering</td>
<td>Installing sensors in the dryer</td>
<td>General Manager</td>
</tr>
<tr>
<td>TFMEA number</td>
<td>Failure Mode</td>
<td>Cause of failure</td>
<td>Effects of failure</td>
<td>Present control</td>
<td>Rating</td>
<td>Departments</td>
<td>Recommended activities</td>
<td>Approved by</td>
</tr>
<tr>
<td>--------------</td>
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<td>------------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>1</td>
<td>Case hardening</td>
<td>Over heating of tea</td>
<td>Burnt taste of tea</td>
<td>Manual</td>
<td>7</td>
<td>Quality control</td>
<td>Providing feedback of the dryer temperature and setting an alarm when the temperature is not within the desired limits</td>
<td>General Manager</td>
</tr>
</tbody>
</table>

Table 3.3. TFMEA – Electrical Engineering

Process Name: Drying
Members present: All TFMEA team members
Table 3.4. TFMEA – Quality control

<table>
<thead>
<tr>
<th>TFMEA number</th>
<th>Failure Mode</th>
<th>Cause of failure</th>
<th>Effects of failure</th>
<th>Present control</th>
<th>Rating</th>
<th>Departments</th>
<th>Recommended activities</th>
<th>Approved by</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Production engineering</td>
<td>Taking samples from the dryer output during production and testing the same for ensuring the quality and identifying defects to execute corrective action immediately</td>
<td>General Manager</td>
</tr>
<tr>
<td>1</td>
<td>Case hardening</td>
<td>Over heating of tea</td>
<td>Burnt taste of tea</td>
<td>Defects are identified after production is completed and the samples are sent to the tea tasters for fixing the price in the auction.</td>
<td>9</td>
<td>8 7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Step X: Convening a meeting of TFMEA team to convey the decision of the top management for implementing the TFMEA program

The engineer convenes a TFMEA team meeting in which he conveys the approval of the top management for implementing the actions recommended in the previous meeting. The TFMEA team members reach their respective sections and identify the personnel to implement the recommended actions.

Step XI: Implementation of TFMEA programme

The engineer helps the TFMEA team members and other employees to implement the recommended actions. On completion of the implementation of the recommended actions, the engineer finds that the defect ‘case hardening’ has been overcome in the manufacturing of tea at ABC.

Step XII: Review of implementation of the TFMEA programme

The engineer reviews the implementation of the recommended actions and assesses the quality of tea by reviewing the price fetched by the tea in the market. The engineer finds that the price of the tea increases by 10% as a result of implementing the actions recommended by the TFMEA team. The engineer prepares the comparative Table to indicate that the ABC stands to gain now as a result of overcoming the defect ‘case hardening’ through the conduct of TFMEA programme. This comparative table is shown in Table 3.5.

Step XIII: Informing the results of the implementation of the TFMEA program to the top management

The engineer informs the top management of ABC about the increased price of tea fetched in the market due to the implementation of TFMEA. Further, it is observed that due to the overcoming of the defect ‘case hardening’, the sales volume has increased in a month from 75000 kilograms to 76500 kilograms. If this
increase in market share persists during the forthcoming 12 months, ABC’s annual revenue will be increased by INR 6030000. The calculation details to this effect are shown below.

Table 3.5. Comparative table

<table>
<thead>
<tr>
<th>Status</th>
<th>Annual production of tea in kilograms (kg) A</th>
<th>Average price of one kilogram of tea in Indian National Rupees (INR) B</th>
<th>Total revenue generated in a year (INR) (A×B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>After TFMEA</td>
<td>900000</td>
<td>85</td>
<td>76500000 (X)</td>
</tr>
<tr>
<td>Before TFMEA</td>
<td>900000</td>
<td>80</td>
<td>72000000 (Y)</td>
</tr>
</tbody>
</table>

Increase in revenue (X - Y) = INR 4500000

→ Sales volume in the last month
before implementing the TFMEA = 75000 kilograms  

   (1)

→ Price of tea before implementing the TFMEA = INR 80  

   (2)

→ Revenue earned by the ABC in the last month
   before overcoming the defect ‘case hardening’ (1×2) = INR 6000000  

   (3)

→ Sales volume in the current month = 76500 kilograms  

   (4)

→ Current price of tea after implementing the TFMEA programme
   and thus, overcoming the defect ‘case hardening’ = INR 85  

   (5)

→ Revenue earned by the ABC
   in the current month (4×5) = INR 6502500  

   (6)

→ Revenue gained by the ABC due to 2% increase
   in market share and 6.25% increase in price due to the implementation of the TFMEA programme (6-3) = INR 502500  

   (7)
Annual revenue gain due to the implementation of the TFMEA programme = $12 \times 502500 = \text{INR} \ 6030000 \quad (8)$

On seeing the above financial gains, the top management imbibles interest to implement TFMEA programme to solve other quality failures encountered in the processing of tea. The top management also requests the engineer to continuously monitor the performance of subsequent TFMEA teams to be formed to solve other quality failures encountered in the manufacturing of tea.

As enumerated above, 13 distinct steps are required to be carefully followed to implement the TFMEA programme in a company manufacturing tea. An interesting part of implementing TFMEA programme is that, its outcome is measured in terms of the price of the tea that is fetched in the market. As money is the language of business (Swarr, 2006), this financial measure would be useful in assessing the effectiveness of TFMEA implementation in companies manufacturing tea. However, TFMEA implementation in a tea manufacturing company has to be carried out as fast as possible as tea is a perishable food commodity. In case a failure is encountered during the manufacturing process, it is difficult to put the tea shoots on hold for a very long period. If there is a need to put the tea shoots under hold, the withering process may be extended by 12 hours by slowing down the rate of withering of the tea shoots. However, it is not possible to put the tea shoots on hold beyond 12 hours as it is a perishable food product. Therefore it is imperative that the TFMEA team has to work effectively in tea manufacturing companies in a time bound manner to overcome all possible failures.

3.4. CONCLUSION

In this chapter the nuances of manufacturing tea have been described. Besides the major quality defects of tea have been enumerated. It has been suggested that, in order to produce high quality tea by overcoming these defects, TFMEA has to be applied. Thus, it has been apprised that, the implementation of
TFMEA in the tea manufacturing companies will be a successful endeavor towards achieving continuous quality improvement of manufacturing tea. The result of this endeavor will be reflected in the form of high quality of tea produced by the tea manufacturing companies. This high quality of tea will fetch higher prices of tea in the market and will also help in increasing the market share of the company.

Although, TFMEA is a simple technique, certain steps are required to be followed carefully in a tea manufacturing company to gain its acceptance among both laborers and managerial personnel. In this chapter, these steps are illustrated by presenting a hypothetical case study. The expected time of completing one cycle of TFMEA programme has also been indicated while illustrating this hypothetical case study. The method of calculating the financial savings achievable through the implementation of the TFMEA programme has also been delineated in few of these steps. These illustrations will enable the readers who are not exposed to the manufacturing of tea to appreciate the essence of implementing TFMEA programme in the tea manufacturing companies. The practicality of the TFMEA technique was further investigated in the doctoral work being reported here by maintaining the hypothetical case study illustrated in this chapter as the benchmark and conducting implementation studies of the TFMEA programme in two black tea manufacturing companies. The details of these implementation studies are presented in the following two chapters.