Research Article

Ordinal Logistic Regression Model of Failure Mode and Effect Analysis (FMEA) in Direct Compressible Buccal Tablet

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ABSTRACT

The failure mode and effect analysis is a very helpful tool for identifying week point in manufacturing of dosage form. Current available risk analysis techniques are well adapted to industry needs since they were developed for its purpose. Each failure mode was ranked on estimated frequency of occurrence (O), probability that the failure would remain undetected later in the process (D) and severity (S), each on a scale of 1–10 and scale is decided by team. Human errors turned out to be the most common cause of failure modes. Failure risks were calculated by Risk Priority Numbers (RPNs) =O×D×S. Failure modes with the highest RPN scores were subjected to corrective actions and the FMEA was repeated and showing reductions in RPN scores and found improvement index and resulting in improvement indices up to 5.0. Results indicate that the application of FMEA method can solve the problems that have arisen from conventional FMEA, and can efficiently discover the potential failure modes and effects. FMEA is an analytical technique that combines the technology and experience of people in identifying foreseeable failure modes of a product or process and planning for its elimination. It can also provide the stability of process assurance and improve the quality of product.

Keywords: Fishbone diagram of FMEA, FMEA basic steps, FMEA variable, traditional FMEA

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INTRODUCTION

Failure occurs when one or more of the intended functions of a product are no longer fulfilled to the customer's satisfaction. The most critical product failures are those that escape design reviews and in-house quality inspection and are found by the customer. The first step in performing Failure Modes and Effects Analysis (FMEA) in manufacturing of buccal tablet is identification of potential failure modes. These failure modes are listed and then scored based on three aspects of the failure modes occurrence (O), detection (D) and severity (S). FMEA is particularly useful in evaluating a new process prior to implementation and in assessing the impact of a proposed change to an existing process which depends on product and process understanding. FMEA is most effective when it occurs before a design is released rather than "after the fact". The aim of this paper is to demonstrate an application of process failure mode and effect analysis as a performance improvement tool, based on a case analysis of process improvement conducted in an early drug discovery project. Some of the simple techniques that are commonly used to structure risk management by organizing data and facilitating decision-making by few methods e.g. Flowcharts, Check Sheets, Process Mapping, Cause and Effect Diagrams (also called an Ishikawa diagram or fish bone diagram)[1].

TRADITIONAL FMEA

Failure Modes and Effects Analysis (FMEA) is a tool widely used in the aerospace, automotive, and electronics industries to identify, prioritize, and eliminate known potential failures, problems, and errors from systems under design, before the product is released in market for the utilization. Each failure mode was ranked on estimated frequency of occurrence (O),

probability of failure that is undetected later in the process (D) and severity (S), each on a scale of 1–10 value. Human errors turned out to be the most common cause of failure modes. Failure risks were calculated by Risk Priority Numbers (RPNs) these are the product of occurrence, Detection, severity. (RPNs) = O×D×S. Failure modes with the highest RPN scores were subjected to corrective actions and the FMEA was repeated, showing reductions in RPN scores and resulting in improvement [2].

BASIC ANALYSIS PROCEDURE FOR FMEA

The basic steps for performing a failure mode and effects Analysis (FMEA)

- Assembling a team
- Establish the rules
- Collections of information
- Identify the items or processes to be analyzed
- Identify the functions, failure, effects, causes and controls for each item or processes to be analyzed
- Evaluate the risk associated with the issues identified by the analysis
- Assign corrective actions
- Perform corrective actions and re-evaluate risk
- Distribute, review and update the analysis as appropriate

Failure Modes and Effects Analysis (FMEA) variable

A. Occurrence: Occurrence is defined as frequency of the specific failure that can cause result in the "failure mode". Occurrence is categorised in the range of 1 to 10 Occurrence should refer to the probability of cause → a particular failure mode → a particular effect/event. In mathematical terms: Probability of failure = (Probability of cause) × (Probability of failure given the cause)
B. Severity: Severity is categorised in the range of 1 to 10 and It is totally depend on the seriousness of the potential failure mode.
C. Detection: Detection methods will detect the potential failure mode before the product is released for production for design or for process before it leaves the production facility. Sometimes confusion surrounding this index, so that we decide give the value 1 for all fields. It also categorised in the range of 1 to 10.

MATERIALS AND METHOD

Materials:

Availability of material and work was done from Government College of pharmacy, Amravati, Maharashtra.

Method:

Teams followed the same FMEA introduction course and performed their FMEA according to the international standard for FMEA [3]. The members with the same background had a comparable level of experience in their field.

1. **Selection of the process:** The importance of the process in terms of the impact of potential failures was taken into account as selection criteria. Evaluation using FMEA works best on processes that do not have too many sub processes.
2. **Review of the process:** The process was analyzed and elaborates in a flowchart and the process design was studied thoroughly for the efficient output.
3. **Brainstorm potential failure modes:** Each stage of the process was studied and identifies the ways it could potentially fail or the things that might go of wrong that should be analyse by the help of experience of team.
4. **List of potential effects of each failure mode:** List of the potential effects on process and their probable failure were prepared. Cause and Effects analysis should be elaborate by fishbone diagram.
5. **Assign a severity rating for each effect:** Each effect was given its own severity rating from 1 to 10, with 10 being the most severe and 1 being less. To quantify or prioritize the effects, Pareto analysis was used.
6. **Assign an occurrence rating for each failure mode:** After collecting data on the factors responsible for the failure of the product, the failure frequency was determined and it were rated appropriately from 1 to 10, with 10 being the most likely and 1 being less occurs.
7. **Assign a detection rating for each failure mode and effect:** List of all controls currently in place to prevent each effect of a failure from occurring was prepared and a detection rating was

assigned for each item (from 1 to 10, with 10 being a low likelihood of detection).

8. **Calculation of the risk priority number (RPN) for each effect:** RPN was calculated by multiplying the severity rating with that of occurrence rating by the detection rating.
   (RPNs) = O×D×S
9. **Prioritize the failure modes for action:** Depending upon calculation and analysis carried out, the priority order was decided.
10. **Taken action to eliminate or reduce the high risk failure modes:** The action to be taken for each high risk failure was determined and a person was assigned to implement the action /change.
11. **Improvement index (II):** After elimination or reduction of failure than calculate the improvement index [5].
    II = (RPN before improvement) / (RPN after improvement)

Flow diagram for the production of the controlled release direct compression buccal matrix tablet (**Figure 1**) [4].

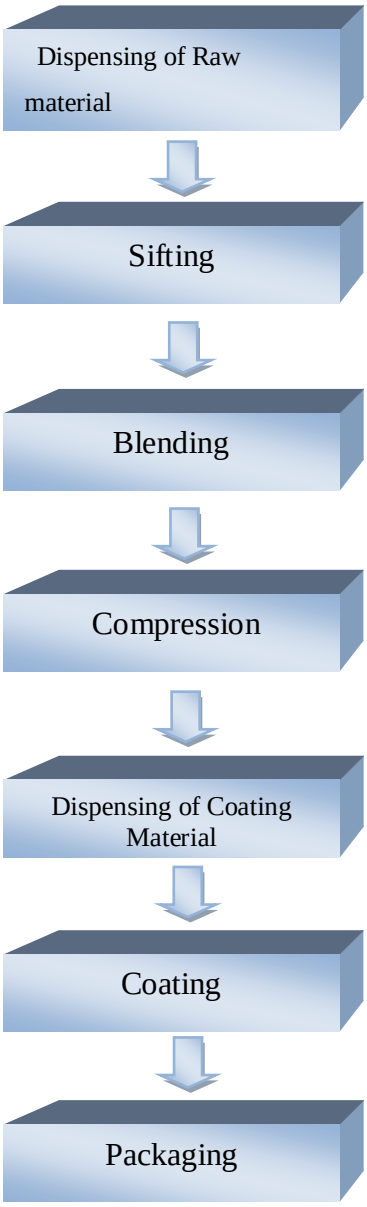

Figure 1: Flow diagram of direct compressible buccal matrix tablet

Table 1: Score scale for frequency of occurrence

Score scale for frequency of occurrence (o) of failure mode defined by team (**Table 2**)

Failure	Probability of failure	Occurrence ranking
Very high: (failure is all most inviolable)	≥ 1 in 2	10
	1 in 3	9
High: (repeated failure)	1 in 8	8
	1 in 20	7
Moderate: (occasional failure)	1 in 80	6
	1 in 400	5
	1 in 2000	4
Low: (relatively few failure)	1 in 15000	3
	1 in 150000	2
Remote: (failure is unlikely)	1 in1500000	1

Table 3: Score scale for severity for severity

Score scale for severity for severity (s) of failure mode defined by team (**Table 2**)

Severity	Effect of severity	severity ranking
Hazardous without warning	When a failure mode affects safe device operation without warning/ People can get severely wounded	10
Hazardous with warning	When a failure mode affects safe device operation with warning	9
Very high	Loss of primary function	8
High	Highly reduced level of performance	7
Moderate	Reduced level of performance	6
Low	Slightly reduced level of performance	5
Very low	Defect noticed by most of customers	4
Minor device	Defect noticed by average customers	3
Very minor	Defect noticed by discriminating customers	2
None	Almost no effect	1

Table 4: Score scale for probability of detection

Score scale for probability of detection of failure mode defined by team (**Table 3**)

Detection	Criteria	Detection Ranking
Impossible to detect	No known techniques available	10
Remote detection	Only unreliable technique available	9
Very slight detection	Proving durability tests on products with system components installed	8
Slight detection	On product with prototypes with system components installed	7
Low detection	On similar system components	6
Medium detection	On preproduction system components	5
Moderate detection	On early prototype system elements	4

Good detection	Simulation and modelling in early stage	3
High chance of detection	Proven analysis available in early design stage	2
Certain to detect	Proven detection methods available in concept stage	1

Failure modes those are widely affecting the manufacturing of direct compressible buccal matrix tablet (**Figure 2, 3, 4**)

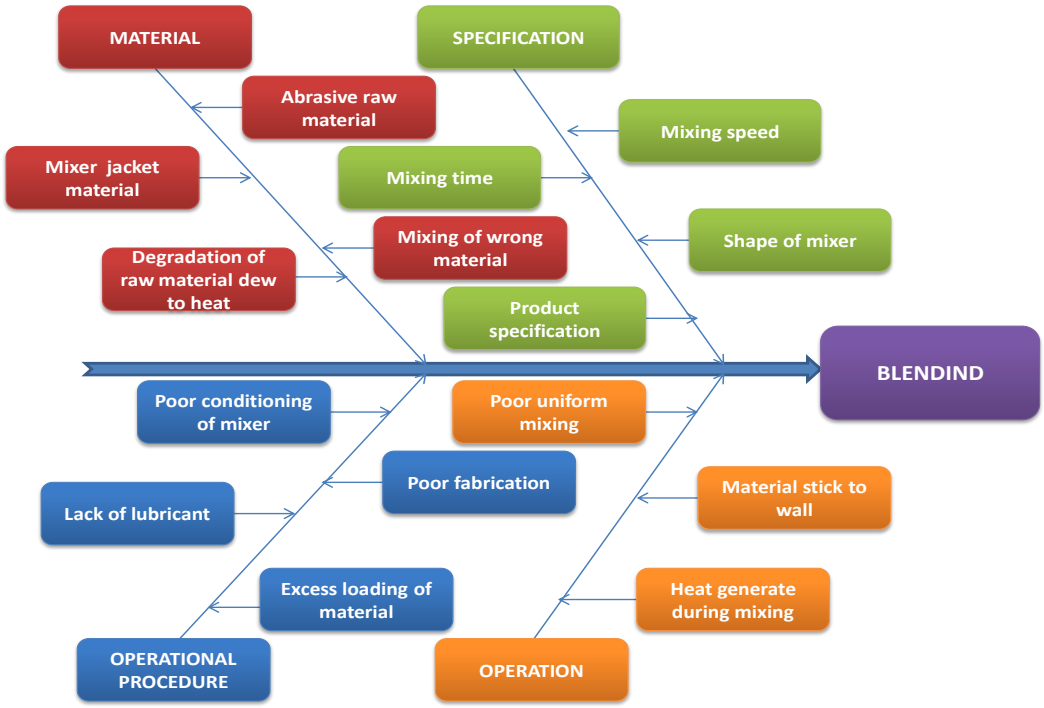

Figure 2: Fishbone diagram of FMEA for Blending of Raw material

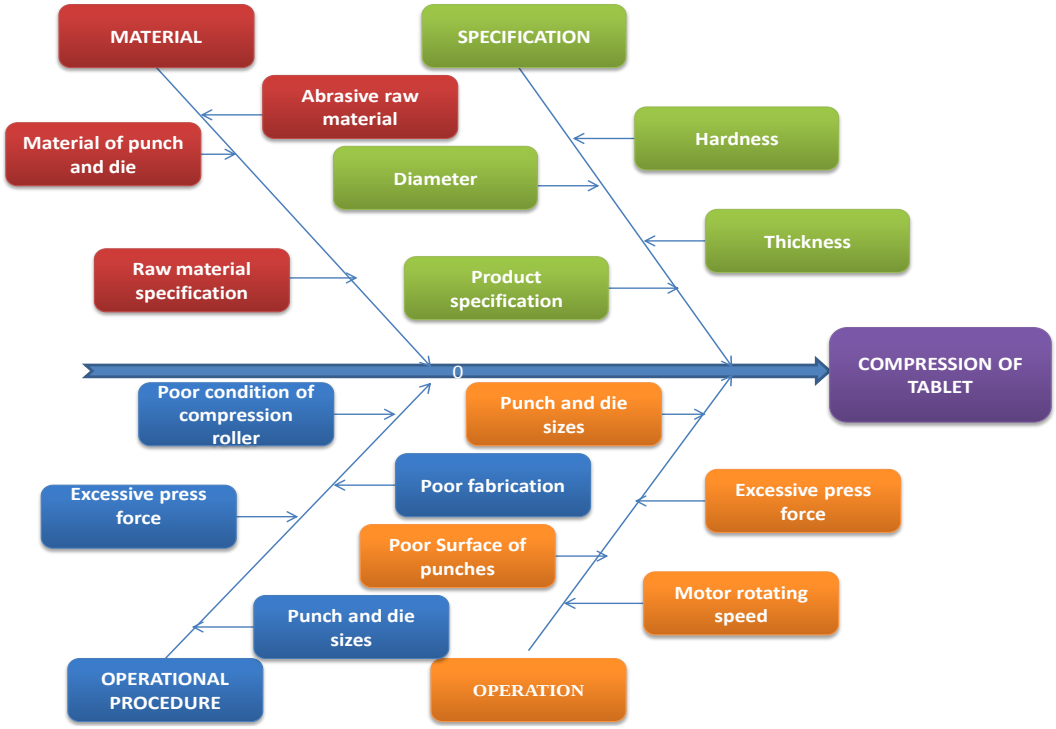

Figure 3: Fishbone diagram of FMEA for Compression of tablet

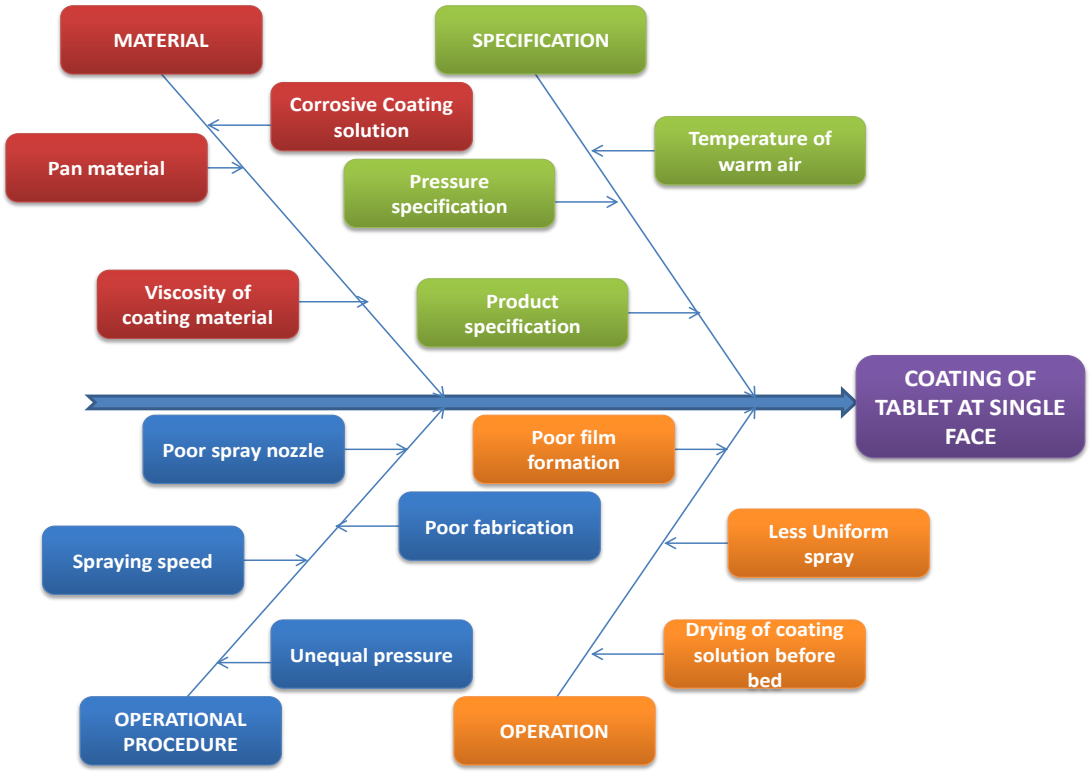

Figure 4: Fishbone diagram of FMEA for Compression of buccal tablet at single face

Table 4: Form of FMEA

F.M.E.A. No						Prepared by									
Date of preparation						Approved by				FMEA revision date					
Process	Potential failure mode	Potential effect of failure	S	Potential causes	O	Current process control	D	RPN	Recommended action	Person Responsible	Action Result				
											Action taken	S	O	D	II
Sign.															

Operative application of methodology

The FMEA design and implementation requires a careful knowledge of the system. Before reporting of the practical application of the FMEA (as evaluation scales definition, FMEA form choice, system risk level calculation), it is important to the extensive collection of data and information about products, production lines and machinery through visits to the production plants and personnel interviews. The adaptation of FMEA to the company manufacturing process required a great effort by the team (**Table 5**).

Table 5: Process steps and failure mode of direct compressible buccal matrix tablet was defined by team

Failure mode	Process	Potential failure mode
1	Dispensing of material	Dispensing of wrong material
2	Temperature and humidity	Material does not meet specification
3	Sifting	Non uniformity of particle
4.1	Mixing	Mixing time & speed
4.2	Mixing	Heat generate during mixing
4.3	Mixing	Excess load of material
5.1	Compression	Hardness
5.2	Compression	Selection of wrong punch and die
5.3	Compression	Selection of both wrong punch and die
5.4	Compression	Improper die filling
6.1	Coating	Mixing of solution in wrong proportion
6.2	Coating	Spraying rate
6.3	Coating	Distance of spray gun form tablet bed
7	Packaging	Mixing of final product
8	Storage	Improper storage of finished product

RPN numbers with respect to Occurrence, Severity, and not Detection scores by Failure Modes of direct compressible buccal matrix tablet (**Table 6**)

Table 6: RPN numbers with respect to Occurrence, Severity, and not Detection scores by Failure Modes of direct compressible buccal matrix tablet

Failure mode	Potential effect of failure	S	Potential cause	O	Current process control	D	RPN
1	Contamination in Product	10	Incorrect receiving of material	5	Preliminary Analysis	2	100
2	Contaminated and low grade material	10	Not storage acc. To specification	5	Evaluation of material	1	50
3	Non uniformity	8	Mistake in sieves no	3	Receiving of material	1	24
4.1	Non uniform mixing	8	Not follow BMR	1	Do acc. To BMR	1	8
4.2	Degradation of API dew to heat	8	Speed of mixer	2	Do acc. To BMR	8	128
4.3	Non uniform mixing	6	Not follow BMR	1	Specified quantity loaded in mixer	1	6
5.1	Non uniform release of dose	5	Excess or less compression force	2	BMR for compression force	1	10
5.2	Unspecified diameter and thickness	5	Non uniform drug release	1	Change of punches and die	1	5

5.3	Damage of Punches and die	10	Lack of experience	1	Change of punches and dies	1	10
5.4	Weight variation	6	Flow property of powder	7	Improve flow of powder	1	42
6.1	Poor film formation	7	Lack of experience	6	Change the solution	5	210
6.2	Non uniform weight build up	5	Lack of experience	6	Adjustment of Pressure	1	30
6.3	Droplet develop	5	Lack of experience	5	Adjustment of spray gun	2	50
7	Market complain	7	Improper transporting	3	Recall for product	1	21
8	Market complain	5	Bad storage room	7	Repackaging	1	35

Table 7: Improvement index after taken of corrective action

Failure mode	Recommended action	Action taken	S	O	D	II
1	Raw material receive from approved vender	Provide training to appoint person	10	2	2	2.5
2	Make a list of material and their storage condition	Provide training to appoint person	10	1	2	2.5
3	Appoint experience person	Provide training to appoint person	8	1	1	3
4.1	Strictly follow BMR	Critical parameter highlighted in BMR	3	1	1	2.6
4.2	Strictly follow BMR	Critical parameter highlighted in BMR	8	1	5	3.2
4.3	Strictly follow BMR	Critical parameter highlighted in BMR	5	1	1	1.2
5.1	Strictly apply IPQC	Critical parameter highlighted in BMR	5	1	1	2
5.2	Strictly apply IPQC	Critical parameter highlighted in BMR	5	1	1	1
5.3	Appoint experience person	Provide training to appoint person	10	1	1	1
5.4	Appoint experience person	Provide training to appoint person	6	4	1	1.75
6.1	Strictly follow BMR	Critical parameter highlighted in BMR	7	3	5	2
6.2	Strictly follow BMR	Critical parameter highlighted in BMR	5	4	1	1.5
6.3	Strictly follow BMR	Critical parameter highlighted in BMR	5	3	2	1.6
7	Strictly follow SOP of transportation	Provide SOP & trained to person	7	1	1	3
8	Finishing of floor and room	Finished the floor and room	5	2	1	3.5

RESULTS

Results of the FMEA of the direct compressible buccal matrix tablet procedure before and after the improvements, it show high improvement in process and reduce the high level of risk and also predetermined the severity of risk and their modes (**Table 7**).

DISCUSSION

The outcome of the FMEA clearly shows inconsistency. Failure modes needing urgent corrective actions and the failure modes needing necessary corrective actions identified by the team differ considerably. In particular, four failure modes needing urgent corrective actions those have high RPN number.

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