Development and application of Kano Lean FMEA [KLF] Model in feed products

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Abstract- Usage of various quality assurance models in manufacturing sector plays an important part in developing a quality improvement product with less cost and reduced time. Because of these reasons the application of quality assurance model will ensure the improvement in quality of feed products. This paper outlines the development and application of KANO, Lean and Process FMEA to feed products industry and the integration of these models is required for today's competitive environment and customer satisfacation.

Keywords: KANO, Lean, FMEA, Feed Quality, Quality Control, Pelleting, waste, Risk Priority Number andQuality Assurance.

I. INTRODUCTION

Feed quality represents the major component in the quality of feed products of cattle and poultry production. In some cases, changes in feed processing technology will be dictated, not by animal response, but by other motivations such as regulatory guidelines or human health concerns. A case in points the use of hydro-thermal processes, such as pelleting, extrusion, or roasting to reduce the micro biological load in the feed. These processes have been demonstrated to reduce microbial population to near zero, but may have little or no impact on human health risk. Quality of food of animal origin is nowadays a predominant keyword for everyone in society, basically the consumer and the policymaker, but also the producer and the specialist of animal production. Because of an increasing diversity in the number of species involved and of products marketed fresh or processed, quality of animal products has received many definitions and understandings.

II. LITERATURE REVIEW

A quality feed would supply all nutrients in adequate quantity and in high digestibility and ingestibility Anon (1991). Since actual quality assurance, control policies and procedures must be adapted to the needs of each facility. The need of the hour is to look into details of quality assurance tools in agro industries to enhance the feed quality. In particular Kano, Lean and FMEA models are explored for feed quality. The goal of Kano is to increase customer satisfaction and build long-term trust with customers. By means of classified surveys the products and services can be adapted to the wishes of the customers. A high-quality product creates customer satisfaction. In the 1980s Professor Noriaki Kano developed a model to describe the satisfaction of customers with products or services and to make them measurable. The basic principle of the Kano model is the classification of product characteristics with the three categories Alena Dressen et al.(1994),

(i) Basic (must be) (ii) Performance (one dimensional) (iii) Excitement (delighters)

This model also classifies customer preferences into five categories: attractive, one-dimensional, must-be, indifferent and reverse. The Kano model defines various product attributes that are considered important to the customers. Most traditional techniques identify the importance of the performance of attributes and customer satisfaction as non-linear. It suggests attributes as "must-be", "one-dimensional" or attractive Kano et al.(1984),Berger .C et al.(1993), Matzler et al.(1998), Nilsson-Witell et al.(2005), .The traditional approach to the classification of attributes and Witell et. al., (2013) draws the conclusion that more exploration of other approaches is required. For this reason, we are advised to use the traditional five-level Kano-questionnaire.

The Lean service applications, tools and techniques in service industries researchers and main contributions to the Lean service sector was highlighted by Higor Dos Reis Leite and Guilherme Ernai Vieira (2015). The use of Lean Manufacturing Tools and the corresponding shift in philosophy, in to food and Beverage industries, the application of Lean Manufacturing tools in the production system of these companies was discussed Rui Borges Lopes et al (2015). Dimitrious Folinas et al., (2013) has described the three-step approach for measuring the environmental performance of specific supply chains in agro food sector based on the VSM techniques was proposed and analysed: mainly on production costs, higher risks and competition for resources by the producers. Higor dos Reis Leite and Guilherme Ernai Vieira (2015) has described the Lean service applications, tools and techniques in services industries researchers and main contributions to the Lean service sector. In recent years, there has been more research about FMEA application in the healthcare system Hu-Chen Liu, et al (2014). FMEA has extensively used as a powerful tool for safety and reliability of products, industries partic ularly, nuclear, aerospace, automotive, chemical, mechanical, medical technologies and electronics Sharma, R. K., Kumar, D., Kumar, P. (2005). FMEA is a widely used by reliability practitioners in America, European and Japan manufacturing companies Chen J. K. (2007).

In general, the risk priorities of failure modes through the Risk Priority Number (RPN), are calculated as a product between the probabilities of the severity (S), occurrence (O) and detection (D) of failure. That is RPN = S × O × D The three risk factors (S, O, D) are evaluated using the 10-point scale. Chang, K. H et al. (2010), Z. Yang nad J. Wang et al.(2015). Those failure modes and causes that have the highest scores should then be addressed through product redesign. A general FMEA framework for capturing the failures due to system/component interactions at the product architecture (PA) level Nepal, B. P. et al.,(2008). FMEA innovation can become a more powerful tool for safety and reliability analysis of systems, processes, designs and services in the organization when know the risk factor and risk priority method are appropriate and suitable to the specific risk evaluation problems Abdelgawad, M., & Fayek, A. R. (2010). Sibel Ozilgen (2013) conducted a Failure mode and effect analysis for dairy product manufacturing and Implementation of the recommended actions appeared to have reduced the RPN values below the acceptable limit. It has been widely used by manufacturing companies for quality and safety assurance. Near the beginning and steady use of FMEAs in the design process let to the engineer to drawing out failures and manufacture dependable, protected, and customer satisfying goods. FMEAs also carry chronological information for use in upcoming product development Bo Bergman & Bengt Klefsjo (2010).

III.DEVELOPMENT OF KANO LEAN FMEA [KLF] MODEL

The KLF Model (Shown in Fig 1) has been developed based on two important traditional models, namely, KANO, LEAN and FMEA .The KLF Model has been developed based on two important traditional models, namely, KANO, LEAN and FMEA . The integration of these models was developed in a stage wise manner..The validation process of the model was built in a stage wise fashion. The following are the steps for the development of KLF Model

STEP-1: REQUIREMENT ANALYSIS

Categorize the requirements and prioritize them based on the expectation of the customer needs and satisfaction level using Kano model. Get the product requirements from the customers or users with all its functionalities and features of project using Kano model.

STEP-2: CATEGORIZE AND PRIORITIZE REQUIREMENT

Categorize and prioritize the requirements in the KLF model

STEP-3: IDENTIFY THE CRITICAL-TO-QUALITY (CTQ)

Identify the Critical-To-Quality (CTQ) or defects or new requirements in the software development phases and eliminate the unwanted process and implement the main functionality in the process.

STEP-4: THOUGHT PROCESS MAPPING (TPM)

Document the CTQ or defects or new requirements and solve the issues by Thought Process Mapping (TPM) through which we can visualize the actual problem ,and we can apply all ideas to solve the problem or issue.

STEP-5: CAUSE EFFECT ANALYSIS AND BRAIN STORMING

Perform cause effect analysis and Brain Storming techniques to encourage creativity

STEP-6: FAILURE MODE EFFECTS ANALYSIS (FMEA)

Identify non-value added process using Failure Mode Effective Analysis (FMEA)

STEP-7:RISK PRIORITY NUMBER (RPN)

Compute the Risk Priority Number (RPN) using the formula

RPN=Severity * Occurrence * Detection

STEP-8: CALCULATE THE RISK PRIORITY NUMBER (RPN 1 & RPN 2)

Check if the specific changes in the process have desired effects and their causes by calculating the RPN 1 and RPN2 .If new process flow is more effective than the current process continue the process otherwise repeat the step 1 to 9

STEP-9:VALIDATE THE KLF MODEL USING STATISTICAL ANALYSIS

The KLF model has been validated using statistical analysis.

IV RESULTS AND ANALYSIS

This work is basically used for upgrading the quality of the feed product using KLF. The impact of this model is given below by examining in the leading manufacturing company in India. Application of KLF Model in a leading feed mill in India was carried out which are shown in Table I (Kano) and Table II (Kano) and Lean was shown in Figure 2. To reduce the system risk level, it is decided to intervene in the system when the RPN was equal to or greater than a threshold value of 50, or when the severity of the failure was considered too high to permit the potential occurrence of the failure. The reason of this choice is that with a statistical confidence of 95% and a maximum number possible for RPN of 1000(10 X10 X10), the threshold is 5% of 1000. The intervention was based on the identification of a list of “Recommended Actions” (Shown in the Table III) that could prevent the failures, reducing the rate of occurrence and detection. Recommended Actions The criteria used to evaluate these failures were the amount of damage caused to the production in terms of lost production volume, idle time of the plants, waste of raw material and resources, maintenance costs, etc. Observing the threshold RPN, it can classify the risks into corrective and non-corrective risks. Risk that has RPN more than 50 are categorized as corrective risk otherwise categorized as non-corrective risk. The reading of the table reveals the potential RPN failures individuated in the production cycle. There are reasons for this result; high values of occurrence and detection and high value of severity. To reduce that when a problem is discovered, it should be addressed and resolved as soon as possible. These failures can be easily prevented through the execution of the recommended action such as periodic maintenance of the machines, SOPs and training the operators.

V. CONCLUSION

An introduction and detailed literature study about the various quality models was discussed ie Kano, Lean and FMEA. Their applicability in the area of feed products was searched. The Literature study highlights that Kano, Lean and FMEA models has only limited work and carried out independently in the area of feed products. The literature study shows that development and application of Kano, Lean and FMEA model was not carried out earlier in the feed products. The development of these models for Agro Industry (feed products) is an innovative approach. The KLF model was developed and applied in a feed mill for feed products and it shows considerable improvement in quality. This is a pioneer work in feed products.

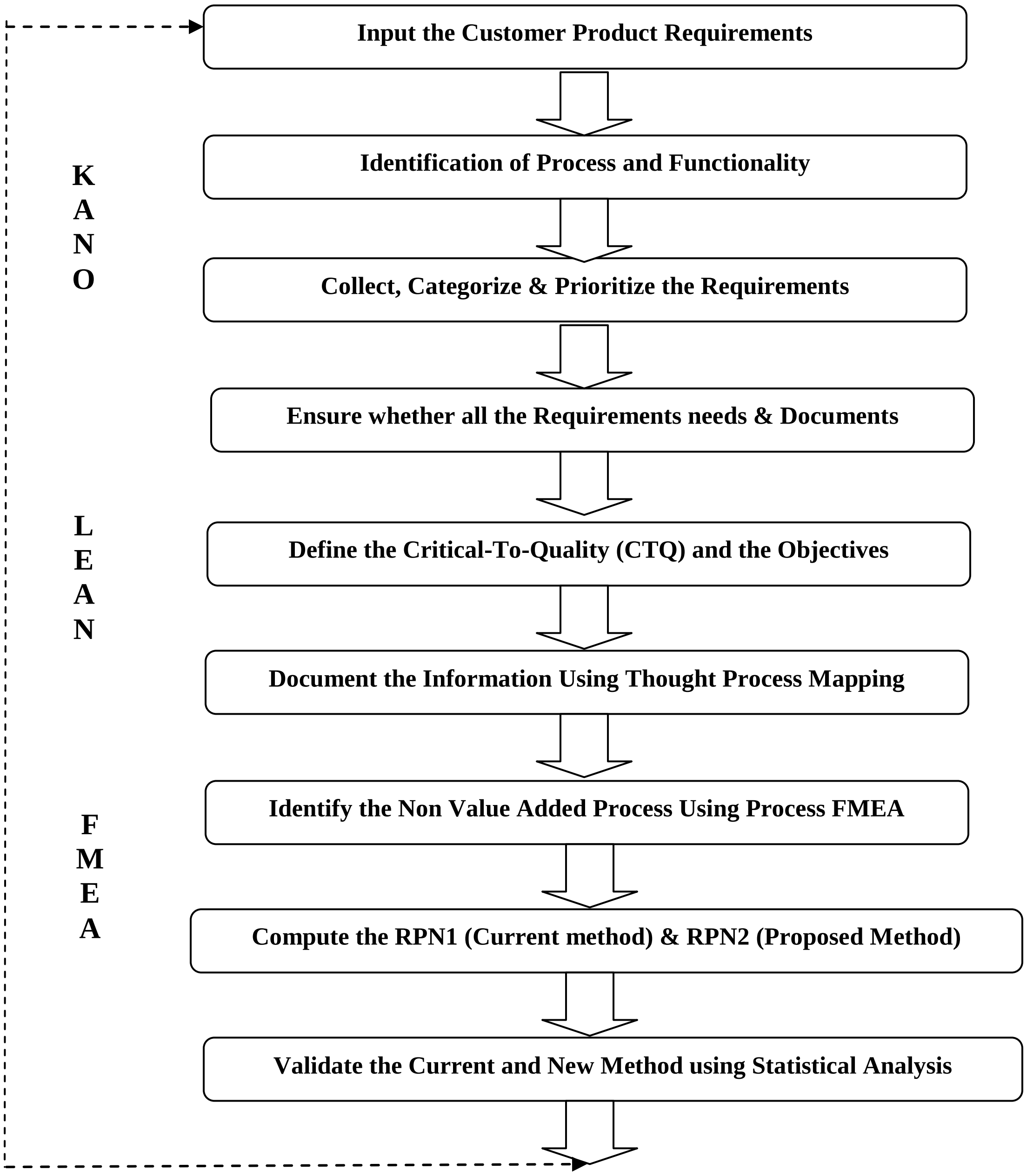

Figure 1: Kano Lean FMEA [KLF] Model

Table 1: Kano Questionnaires and their respones

Q01	**conversion ratio should be proper**								
		Percentage	35%	0%	5%	55%	5%	0%	100%
Q02	**Ingredients cost should be reduced**	Responses	4	1	0	13	0	2	20
		Percentage	60%	5%	0%	5%	0%	10%	100%
Q03	**Mixing time should be appropriate**	Responses	15	0	0	5	0	0	20
		Percentage	75%	0%	0%	25%	0%	0%	100%
Q04	**Foreign particles should not be added into the ingredients**	Responses	10	0	0	9	1	0	20
		Percentage	50%	0%	0%	45%	5%	0%	100%
Q05	**Pellet durability should be maintained**	Responses	3	0	0	14	1	0	20
		Percentage	15%	0%	0%	80%	5%	0%	100%
Q06	**Excessive ingredients (fat) should be avoided**	Responses	16	0	0	4	FALSE	0	20
		Percentage	80%	0%	0%	20%	0%	0%	100%
Q07	**Moisture level should be less**	Responses	13	2	0	13	0	0	20
		Percentage	35%	0%	0%	65%	0%	0%	100%
Q08	**Feed color should be maintained**	Responses	14	0	2	2	2	1	20
		Percentage	70%	0%	10%	10%	5%	5%	100%
Q09	**standard odour should be maintained**	Responses	19	0	0	1	0	0	20
		Percentage	95%	0%	0%	5%	0%	0%	100%
Q10	**Granules size should be accurate**	Responses	15	1	0	2	0	2	20
		Percentage	75%	5%	0%	10%	0%	10%	100%
Q11	**Reduced intake of feed**	Responses	10	2	2	2	2	2	20
		Percentage	45%	15%	10%	15%	9%	5%	1%
Q12	**Ingredient should have a sustainable duration**	Responses	14	1	1	8	2	2	20
		Percentage	5%	65%	5%	5%	10%	10%	100%
Q13	**Conditioning temperature should be standard**	Responses	1	12	1	1	2	2	20
		Percentage	60%	10%	10%	15%	5%	10%	100%
Q14	**Cooling time should be proper**	Responses	13	2	1	2	1	1	20
		Percentage	65%	10%	5%	10%	5%	5%	100%
Q15	**Bag weight should be proper**	Responses	5	0	5	3	3	3	20
		Percentage	25%	0%	25%	15%	15%	15%	100%

Q16	**Powdery in bags should be avoided**	Responses	6	1	2	5	5	1	20
		Percentage	30%	20%	20%	10%	10%	10%	100%
Q17	**Improper stitching of bags should be avoided**	Responses	9	3	2	1	2	3	20
		Percentage	45%	5%	5%	5%	20%	20%	100%
Q18	**Delay in delivery of products**	Responses	12	0	5	13	8	0	20
		Percentage	65%	0%	0%	0%	35%	0%	100%

TABLE II. SELF-STATED IMPORTANCE RANKING

Question	Self-Stated Importance Ranking
Q01	7.9
Q02	8.6
Q03	7.0
Q04	6.5
Q05	6.4
Q06	5.7
Q07	7.2
Q08	7.6
Q09	7.9
Q10	8.0
Q11	3.4
Q12	4.4
Q13	7.3
Q14	6.0
Q15	4.9
Q16	4.4
Q17	4.3
Q18	4.1

Fig.3 Thought Process map (Lean Model)

TABLE III. FMEA TABLE

Operation	Failure mode	Severity	Effect	Occurr e nce	Cause	Detection	RPN
Raw material intake	Operator didn‟t separate raw materials	7	Mixing of hard and soft material	8	Operator fatigue	2	112
	Trolley cannot work properly	4	Manually lift up the sack by operators	6	Irregular maintenance	3	72
	Material spilled out from sack	5	Raw material shortage while processing	6	Operator‟s careless in filling sack	4	120
	Minibean m/c stops suddenly	5	Temporarily stops process	6	Irregular maintenance	3	90
	Minibean valve is opened	6	Materials will be spilled out	5	Irregular maintenance	3	90
	Temporary storage tank is too full	8	Can‟t accommodate further materials	6	Didn‟t check the storage tank condition	5	240
	Material spilled out from minibean m/c	6	Raw material shortage while processing	7	Minibean machine valve is opened	5	210
	Filling additional substances and CPO(crude Palm Oil) into wrong storage	5	Mixing of CPO with additional substances	6	Lack of SOP(standard operating procedure)	3	90
	Mixing happens between additional substances and CPO oil	6	Mixing of CPO with additional substances	8	Operator fatigue	3	144
	Hard material intake machine valve is opened	5	Materials will be spilled out	6	Irregular maintenance	4	120
	Intake machine stops suddenly in sending hard raw material	9	Temporarity stop process	4	Irregular maintenance	3	108
	Hard material spilled out	5	Material shortage while processing	5	Intake valve is opened	4	100
	Grinder machine stops suddenly	9	Temporarily stop process	5	Irregular maintenance	3	135
	Hard material is not fully grinded	5	Decrease in product quantity	4	Operator oversight to arrange the grinding machine velocity	5	100
	Grinders machine‟s valve is opened	6	Materials will be spilled out	5	Irregular maintenance	4	120
	Some of material are still in hard form	6	Gross product amount differs with the amount material	3	Grinder velocity doesn‟t fit with hard material dimension that is processed	5	90
	Didn‟t check grinder m/c based on SOP	5	Products will be out of specitfication	5	Less knowledge about machine handling	5	125
	Too much additional substances and CPO oil are filled into minibean m/c	6	Material can‟t be filled into minibean m/c	6	Didn‟t check the minibean m/c condition	4	144
	Substances and CPO oil are spilled out	4	Material shortage while processing	5	Minibean m/c valve is opened	4	80
	Smooth material intake m/c	5	Materials will be	5	Irregular maintenance	4	100

	valve is opened		spilled out				
Mixing	Smoother materials are spilled out	5	Material shortage while processing	5	Intake valve is opened	4	100
	Pollutants mixed with smoother material	10	Products will be out of specification	3	Irregular machine maintenance	4	120
	Incorrect mixing composition in each classification	7	Products will be out of specification	3	Less knowledge about product receipt	5	105
	Mixer machine stops suddenly	9	Temporarily stop process	5	Irregular maintenance	3	135
	Mixer machine‟s valve is opened	5	Materials will be spilled out	5	Irregular maintenance	6	150
	All material aren‟t mixed fully	5	Products will be out of specification	4	Faultiness is setting frequency of mixing from	6	120
	Mistake make in checking mixer m/c	6	Products will be out of specification	4	Lack of SOP	3	72
	Operators accidents	10	Creates loss in company level	1	Operator didn‟t wear safety equipment	4	40
	Gross products are out of composition	8	Gross product will be reworked	2	Pollutants inside mixer m/c	4	64
	Sample taker equipment aren‟t sterilized	6	Can contaminate or mix into the product	5	Unscheduled cleaning for sample taker equipment	4	120
	Composition checking equipment aren‟t sterilized	6	Can contaminate or mix into the product	5	Unscheduled cleaning for sample checker equipment	4	120
	Gross products are spilled out	5	Material shortage while processing	5	Intake valve is opened	4	100
Pelleting	Pollutants mixed with gross product	10	Products will be out of specification	3	Irregular machine maintenance	4	120
	Stacking some products on intake m/c surface	4	Material shortage while processing	6	Irregular machine maintenance	6	144
	Pellet machine suddenly stops	9	Temporarily stop process	5	Irregular maintenance	3	135
	Pellet machine‟s valve is opened	5	Materials will be spilled out	5	Irregular maintenance	4	100
	Pellet product is spilled out	5	Material shortage while processing	5	Pellet machine valve is opened	4	100
	Product aren‟t fully becoming pellet	4	Products will be out of specification	4	Faultiness in inputting of velocity‟s frequency of pellet m/c	6	96
	Pollutants stick on pellets	10	Product will be defective	3	Irregular maintenance	4	120
	Colour difference on gross products	4	Products will be out of specification	2	Impurities contaminate gross products	4	32
	Stacking pellet products on intake	5	Production will be slower		Irregular maintenance	4	120
Crumbling	Pellets aren‟t castaway	3	Pellet product quantity will be reduced		Intake machine‟s sieve is opened	4	60

	Crumble machine suddenly stops	9	Temporarily stop process		Irregular maintenance schedule	3	162
	Crumble machine‟s valve is opened	5	Pellet products will be spilled out		Irregular maintenance schedule	4	100
	Pellet aren‟t fully formed into ball form	7	Products will be out of specification		Faultiness in inputting of velocity‟s frequency of crumble m/c	5	175
	Crumble products are spilled out	5	Crumble product quantity will be reduced		Crumble machine‟s valve is opened	4	100
	Pollutants adhere on crumble products	10	Product will be defective		Irregular maintenance schedule	4	80
cooling	Products stick on intake m/c surface	4	Production will be slower	6	Irregular maintenance schedule	4	96
	Leakage on intake machine‟s pipe	7	Product quantity will be reduced	3	Irregular maintenance schedule	4	84
	Cooler machine‟ s valve is opened	5	Many crumble products are spilled out	5	Irregular maintenance schedule	4	100
	Cooler machine suddenly stops	9	Temporarily stop process	5	Irregular maintenance	3	135
	Cooler m/c‟s fan doesn‟t operate	9	Temporarily stop process	6	Irregular maintenance	3	162
	Products aren‟t fully becoming colder	4	Production will be slower	4	Faultiness in inputting of velocity‟s frequency of cooling m/c	4	64
	Operator makes mistake in inspection	5	Defective products are processed	5	Lack of operator‟s knowledge	3	75
Sieving	Pollutants contaminate product	8	Products will be out of specification	2	Pollutants are attached to engine intake	4	64
	Sieve machine‟s valve is opened	5	WIP material are spilled out	5	Irregular maintenance	5	125
	Sieve machine suddenly stops	9	Temporarily stop process	6	Irregular maintenance	3	162
	Resultant quantity doesn‟t appropriate	5	Unable to meet the product demand	5	Sieve m/c filters clogged by pollutants	5	125
	Impurities that are drifted from the sieve	5	Products will be out of specification	3	Sieve engine filter is leaked	5	75
	Granules settles in sieve‟s surface	4	Products quantity will be reduced	3	Too moist intake machine	4	48
	Operator makes mistake in inspection	5	Products will be out of specification	6	Lack of operator‟s knowledge	5	150
Packaging	Inaccurate measurement of weighing m/c	5	Products will be out of specification	3	Operators mistake in resetting the scales	5	75
	Forget to reset weight categories based on the type of sacks	5	Product amount don‟t match sack‟s size	3	Lack of operator‟s knowledge	5	75
	Product barrier valve doesn‟t work	4	Temporarily stop process	6	Irregular maintenance	4	96
	Faucet valve is clogged	4	Temporarily stop process	5	Irregular maintenance	4	80
	Wrapping sack is broken	7	Leakage in filling	5	Operators didn‟t check	4	140

			product into the sack		the sack before		
	Products are spilled during charging	5	Product quantity will be reduced	5	Operators fatigues	5	125
	Sack straps don‟t function properly	8	Products inside the sack will be spilled out	6	Irregular maintenance	4	192
	Packaging machine suddenly stops	9	Process delay	3	Irregular maintenance	4	108
	Sack‟s product wrapping is leaked	6	Product volume is reduced	5	Operators didn‟t check the sack before	5	150
	Misplaced finished goods in warehouse	7	Finished goods will be mixed	3	Operator fatigues	8	168
	Hand truck m/c suddenly stops	5	Shipment process will be disturbed	6	Irregular maintenance	5	150

REFERENCES

[1] Behnke, K.C. (1994) Factors affecting pellet quality. Maryland Nutrition Conference. Dept. of Poultry Science and Animal Science, College of Agriculture, University of Maryland, College Park.

[2] Dr. Keith C. Behnke (2001) „Factors influencing Pellet quality‟, *Department of Grain Science and Industry*, Kansas

[3] M. Thomas D. J. Van Zuilichem AF. B. Van der Poel (1997) „Physical quality of pelleted animal feed. Contribution of processes and it s conditions‟.,*Animal Feed Science and Technology*, Volume 64, Issues –2 – 4, pages 173 – 192.

[4] A. Aumaitre (1999) „Quality and safety of animal products‟., *Livestock Science*, Vol. 59, Issues 2 – 3, pages113 – 124. https://doi.org/10.1016/S0301-6226(99)00020-2

[5] ANON. (1991). Diseases of animals (poultry feeds) order, Statutory instrument 364 of Government Stationery Office, pp. 1–9.

[6] Gerrit willem ziggersa Jaques Trienekenst (1999) „Quality assurance in food and agri-business‟. Supply chains: Developing successful partnerships,. *International Journal of Production Economics*, Elsevier. Vol. 60-61, pages 271 – 279. https://doi.org/10.1016/S0925-5273(98)00138-8

[7] Justyna Knaflewska and Edward Pospiech (2007) „Quality Assurance systems in food industry and health security of food‟ *ACTA Scientiarum Polonorum Technol. Aliment.*, Issues 6 (2) 2007pp 75 – 84. http://www.food.actapol.net/issue2/volume/7_2_2007.pdf

[8] Alena Dressen and Jannik Elfer. Dreessen, Jannik Elfers and Devlin SJ (1994) „Review of the Kano model – practical example tourism industry‟, , Dong HK.

[9]Cooper, H. M. (1998). Synthesizing research: A guide for literature reviews (Vol. 2). *Sage Alena*

[10]Kano, N., Seraku, N., Takahashi, F., & Tsuji, S. (1984). Attractive quality and must-be quality, *The Journal of the Japanese Society for Quality.*

[11]Berger, C., Blauth, R., Boger, D., Bolster, C., Burchill, G., DuMouchel, W., Pouliot, F., Richter, R., Rubinoff, A., Shen, D., Timko, M. and Walden, D. (1993). Kano‟s methods for understanding customer-defined quality. *The Centre for Quality of Management Journal*, 2(4), 2–36.

[12]Matzler, K., & Hinterhuber, H. H. (1998). How to make product development projects more successful by integrating Kano's model of customer satisfaction into quality function deployment. *Technovation*, 18(1), 25-38.

[13] Matzler, K., Hinterhuber, H. H., Bailom, F., & Sauerwein, E. (1996). How to delight your customers. *Journal of Product & Brand Management*, 5(2), 6-18.

[14]Nilsson-Witell, L., & Fundin, A. (2005). Dynamics of service attributes: a test of Kano's theory of attractive quality. *International Journal of Service Industry Management*, 16(2), 152-168.

[15] **Kano**, N. (**1995)** Upsizing the organization by attractive quality creation. 1999 Development of innovative products using **Kano's** model quality function deployment. *International Journal of Innovation Management* 3, no. 3:271-286 … 1:54-73, 122-132..

[16]Lars Wielll, Martin Lofgren, (2007) "Classification of quality attributes", *Managing Service Quality: An International Journal*, Vol. 17 Issue: 1, pp.54-73,

[17] Higor dos Reis Leite and Guilherme Ernai Vieira (2015) Lean philosophy and its applications in the service industry: A review of the current knowledge; *Production journal* Vol 25 n:3 P 529 -541,

[18] Rui Borges Lopes F. Freitas I Sousa (2015) „Application of Lean manufacturing tools in the food and Beverage Industries‟, vol 10 Issue 3, J. *Technol Manag Innov*;

[19]M.L. Emiliani, D.J. Stec, (2005) "Wood pallet suppliers' reaction to online reverse auctions", *Supply Chain Management: An International Journal*, Vol. 10 Issue: 4, pp.278-287,

[20] Ulla Lantinan and Margit Torkko (2005) The Lean concept in the Food Industry: A case study of contract a Manufacturer:, *International Journal of Food Diustribution Research* 36(3)

[21] Chrysler(1995) Daimler Chrysler Corporation, Ford Motor Company, General Motors Corporation, Third Edition, Potential Failure Mode and Effects Analysis (FMEA) Reference Manual by Adare Carwin Limited.

[22] Hu-Chen Liu, Jian – Xin you Xia – Jun Fan Quing- Lian – Lin (2014) Failure mode and effects analysis using D numbers and grey relational projection method, , *Expert System with applications, Elsevier*, Vol. 41, issue 10, pages – 4670 – 4679.
[23]Bowles, J.B., Peláez, C.E.(1995). Fuzzy logic prioritization of failures in a system failure mode effects and criticality analysis, Reliab. Eng. *Syst. Saf*, 50, 203–213.
[24] Sharma, R.K., Kumar, D., Kumar, P. (2005). Systematic failure mode and effect analysis using fuzzy linguistic modeling, *Int. J. Qual. Reliab. Manage*, 22 (9), 886–1004.
[25] Chen, J. K. (2007). Utility priority number evaluation for FMEA. *Journal of Failure Analysis and Prevention*, 7, 321–328.
[26] Chang, K. H. (2009). Evaluate the orderings of risk for failure problems using a more general RPN methodology. *Microelectronics Reliability*, 49, 1586–1596.
[27] Chang, K. H., & Cheng, C. H. (2010). A risk assessment methodology using intuitionistic fuzzy set in FMEA. *International Journal of Systems Science*, 41, 1457–1471.
[28] Puente, J., Pino, R., Priore, P., & de la Fuente, D. (2002). A decision support system for applying failure mode and effects analysis. *International Journal of Quality & Reliability Management*, 19, 137–150.
[29] Braglia, M., Frosolini, M., & Montanari, R. (2003). Fuzzy criticality assessment model for failure modes and effects analysis. *International Journal of Quality & Reliability Management*, 20, 503–524.
[30] Chin, K. S., Wang, Y. M., Poon, G. K. K., & Yang, J. B. (2009a). Failure mode and effects analysis by data envelopment analysis. Decision Support Systems, 48, 246–256.
[31] Chin, K. S., Wang, Y. M., Poon, G. K. K., & Yang, J. B. (2009b). Failure mode and effects analysis using a group-based evidential reasoning approach. *Computers & Operations Research*, 36(6), 1768–1779.
[32] Gargama, H., & Chaturvedi, S. K. (2011). Criticality assessment models for failure mode effects and criticality analysis using fuzzy logic. *IEEE Transactions on Reliability*, 60, 102–110.
[33] Kutlu, A. C., & Ekmekçioğlu, M. (2012). Fuzzy failure modes and effects analysis by using fuzzy TOPSIS-based fuzzy AHP. *Expert Systems with Applications*, 39, 61–67.
[34] Garcia, P. A. A., Schirru, R., & Frutuoso Emelo, P. F. (2005). A fuzzy data envelopment analysis approach for FMEA. Progress in Nuclear Energy, 46, 359–373.
[35] Abdelgawad, M., & Fayek, A. R. (2010). Risk management in the construction industry using combined fuzzy FMEA and fuzzy AHP. *Journal of Construction Engineering and Management*, 136, 1028–1036.
[36] Nepal, B. P., Yadav, O. P., Monplaisir, L., & Murat, A. (2008). A framework for capturing and analyzing the failures due to system/component interactions. *Quality and Reliability Engineering International*, 24, 265–289.
[37] Guimarães, A. C. F., & Lapa, C. M. F (2004a). Effects analysis fuzzy inference system in nuclear problems using approximate reasoning. *Annals of Nuclear Energy*, 31, 107– 115.
[38] Guimarães, A. C. F., & Lapa, C. M. F. (2004b). Fuzzy FMEA applied to PWR chemical and volume control system. *Progress in Nuclear Energy*, 44, 191–213.
[39] Guimarães, A. C. F., & Lapa, C. M. F. (2006). Hazard and operability study using approximate reasoning in light-water reactors passive systems. *Nuclear Engineering and Design*, 236, 1256–1263.
[40] Guimarães, A. C. F., & Lapa, C. M. F. (2007). Fuzzy inference to risk assessment on nuclear engineering systems. *Applied Soft Computing*, 7, 17–28.
[41] Hamid Reza Feili , Navid Akar , Hossein Lotfizadeh , Mohammad Bairampour , Sina Nasiri (2013) "Risk analysis of geothermal power plants using Failure Modes and Effects Analysis (FMEA) technique",*energy conversion and management* , pp.69-76.
[42]Levent Kurt , Sibel Ozilgen (2013) "Failure mode and effect analysis for dairy product manufacturing: Practical safety improvement action plan with cases from Turkey", *Safety Science*, pp. 195-206

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