Risk Evaluation of Dairy Products Manufacturing Processes Using a Set of Connected Fuzzy Inference Systems

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Abstract: - The objectives of this work are to develop an intelligent system capable of analyzing and evaluating risks in dairy products manufacturing systems. Contaminations from the dairy products and raw milk have contributed to different hazardous Health-related dilemmas around the globe. Having adequate systems in place to prevent these issues is paramount, as dairy products are widely consumed for its nutrition benefit reasons. These benefits can result in catastrophic impacts as a result of failures and unmitigated risk during the industrial processing, thus, the need for proper studying of these failures in dairy production systems is inevitable. Analysing risks associated with dairy products manufacturing help in identifying each failure at every stage of the production. The dairy products manufacturing system risks are classified into four categories namely; Physical, Biological, Chemical, and Environmental risk, which gave a distinctive analysis of the dairy manufacturing processes. Here, a set of five well connected Mamdani Fuzzy Inference System (FIS) models are proposed to solve these dilemmas. The first stage of the study involved gathering data to identify the failure modes using data from operation failures, root-cause analysis log, consumer feedbacks, and the expert's opinions. These data were used to define the membership functions for the first four FISs, with the expert's knowledge and opinions. The output of this first four FISs are then fed into the final FIS to evaluate the risk level of the manufacturing system. The RPN criteria used are occurrences, severity, and detectability, which serve as the fuzzy inputs. Each risk for the failures is evaluated for physical, biological, chemical, and environmental risk, with biological risk contributing the highest risk to the consumers due to the microorganisms.

It is concluded that an implementation of the results from this work will reduce the failures associated with the dairy products manufacturing and also personnel's hygiene, clean environment, and adequate training, will minimize the risk at all categories.

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I. INTRODUCTION

In today's world, dairy products are expanding in importance as it is consumed widely by the younger generation. This high rate of consumption is influenced by a strong market demand for consumption of milk, benefits of milk to child nutrition and a means to generate income, build assets and socio-economic benefits [14]. Milk is mainly obtained from dairy cows, goats, buffalo etc. Raw milk is processed before it can be consumed to reduce the fat content of the milk and add various vitamins and potentially harmful bacteria are destroyed. However, milk can also be transformed into products like yogurts, cheese, and butter, that are the dairy products. etc. Milk and milk products are the highest contributors of protein in children and second in other age groups.

Even with the complexity of the dairy products processes, the need for these products have increased annually due to its benefits. The effect of high rate of consumption also contributes to the 4% annual increase of dairy (Milk) production across the globe. Food and Agriculture Organization of United Nations (FAO) statistics show a steady increase in the dairy products consumption for the past decades and that continues with the world total dairy production sitting at 805 million tons in the year 2015. Following this high consumption, investors venture into the business. Thus, it becomes necessary to understand the production processes as well as the associated risks.

The processes include extraction, grazing, pasteurizing, homogenizing, separation, packaging, and cleaning. The major cause of these risks in dairy products manufacturing is of human, equipment, material, and the processes. Hence, the need to produce safer products is required since milk and milk products are perishable food products [1], research has shown that contaminated and infected milk had caused and will continue to inflict negative impacts on consumers if failures in manufacturing processes of dairy products are not properly accessed and studied.

According to World Health Organization (WHO), food-borne diseases are widespread and becoming increasingly serious threats for both developed and undeveloped countries all over the world. As a matter of fact, the safety and suitability of dairy products for human consumption must be ensured through the implementation of proper hygienic control of milk and milk products throughout the process, from farm to table. Mainly, dairy products manufacturing is affected by four categories of risk; physical, chemical, biological, and environmental risks, which are the failures evaluated in this research. Fuzzy methodology is one of the best tool to analyse risk in manufacturing processes. This is the tool used to access these risks based on three criteria which are: Severity, this is how serious is the failure; Occurrence, this is how frequent the failure occurs; Detectability, possibility to detect the failure.

Dairy farming is the main integral of the dairy products manufacturing. Without raw milk, it would be a challenge to manufacture or produce dairy products. The more emphasizes given to the raw milk sourcing, treatment, and handling, the safer and lessen the negative impact on the consumers. The authors in [1] stated that the samples of rawest milk from the dairy farm used for dairy products manufacturing in Turkey failed a requirement test. This lead to dairy products manufacturers owning dairy farm themselves to minimise the unwelcoming results.

Milk and milk products have gone through different phases since they evolved, and the challenges facing the industry have not been clearly dealt with. There are several issues of foodborne diseases coming from dairy products as recorded in [15]. A most recent multi-state case of listeria that was reported in Pennsylvania was linked to unpasteurized raw milk. The need to monitor every stage of the manufacturing process using risk level of each stage thus becomes pertinent.

In 2007, World Health Organization (WHO) reported that little less than 2 million people lost their lives in 2005 because of diarrheal diseases caused by contaminated foods with dairy products inclusive. These hazardous contaminated foods are causing foodborne diseases globally (both in emerging market, and economically strong markets). Around 8.3% of the world biological related foodborne disease outbreaks are directly caused by dairy products [2].

Therefore, the effective evaluation of the risk in dairy products manufacturing reduces production of contaminated and infected dairy. The traditional Failure Modes and Effects Analysis (FMEA) and its Risk Priority Number (RPN) does not promise success in risk evaluation. This is due to its numerous shortcomings: how different arrangements can give the same output; the lack of expert's opinion in identifying the failure modes; and how a zero value in the criteria indicate no failure or risk.

The need to present a better approach to analyse the risk in dairy products manufacturing is vital. Here, we propose a five (5) Mamdani FISs arrangement using the expert's opinion, and quantitative, linguistic terms to rank the FMEA RPN criteria (Occurrence, Severity, and Detectability). This research will undermine failures and risk associated with the dairy products manufacturing to greatly minimize the risks across all categories (Physical, Biological, Chemical, and Environmental). These, in turn reduce risks associated with the whole dairy products manufacturing systems.

The remaining sections of this Paper are organized as follows. Section 2 elaborates on the proposed methodology; whereas, section 3 presents the experimental results analysis. In section 4, the Conclusions are presented.

II. PROPOSED APPROACH

The proposed model is implemented by a two-stage with five-FIS systems. The first stage (consist of four FISs) analyse the dairy products risks using the FMEA criteria, the inputs (Occurrence, Severity, and Detectability) with expert's knowledge and opinion. Fig. 1 shows the schematic diagram of the proposed model. The output of each one of the Physical, Chemical, Biological and Environmental Failures from the first stage. These Failures are fed as inputs to the final stage FIS; where the final manufacturing system ranking is done. The parameters are defined and ranked based on FMEA methodology to give equal weight to all the criteria.

In the planning of a manufacturing system, it is of the best interest of operation, maintenance, and plant managers to identify potential failures and develop a Standard Operating Procedure (SOPs) before diving into any task. So, it is important to analyse risk by categories since their consequences differ.

The first step of this model required the opinions and inputs from the experts in identifying the failure modes. Next, is to assign the linguistic terms corresponding to each case of the failure mode in the system based on their occurrences, severities, and degree of detection if the failure occurs. The membership functions (MFs) are assigned appropriately based on the linguistic terms defined by the experts, these linguistic terms are used to design the MFs of the proposed models.

The evaluation criteria between 0 and 100 are used in the proposed model. It follows the sequence of the traditional FMEA (O, S, and D) in the ranking of the linguistic term and the MFs evaluation of the failures. The experts were an important component of this work as shown in Fig. 1. Their knowledge and opinions were directed to identifying the failure modes for each category and provided information on the occurrence, severity, and detectability of those identified failure modes.

The experts were formed based on their in-depth knowledge of the manufacturing system and a total of six (6) member committee is appropriate for a medium problem. The committee (experts) includes the Operation manager, Maintenance manager, two (2) Senior Operators, and two (2) Line leaders (Supervisors).

As previously mentioned, there are five FIS models proposed to have a comprehensive evaluation, taking account of what matters in the dairy products manufacturing. As an example, the Fig. 2 shows the Physical Risk model. The other Biological, Chemical and Environmental models have similar structures.

Fig. 3 shows the final Fuzzy Inference System where the Physical, Biological, Chemical, and Environmental risks are the inputs, to rank the risk of a manufacturing system of diary products.

The Trapezoidal MF min and max (equation 1) was adopted for all the models as a result of continuity and due to its simplicity and computational easiness [3]. The linguistic terms that were used are Very_High, High, Medium, Small, and Very Small to give the fuzzy rules of five to the power of three (inputs; O, S, and D).

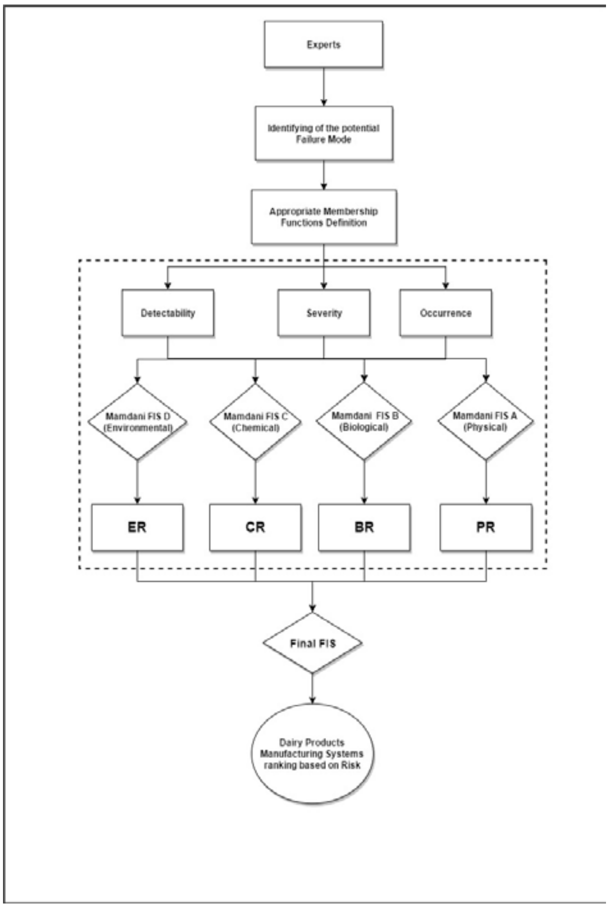

Fig. 1: Proposed Mamdani Fuzzy Inference Systems for Risk Analysis in Dairy Products Manufacturing Systems

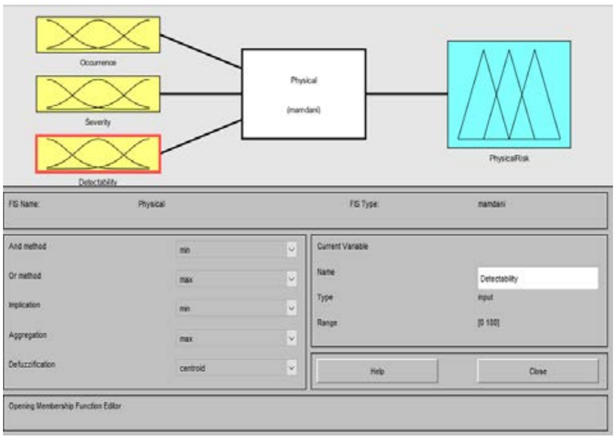

Fig. 2: Mamdani FIS for Physical Risk Model

Each FIS has 125 fuzzy rules, and the final FIS has 625 fuzzy rules. So the entre system has 125 x 4 + 625; for a total of 1125 rules.

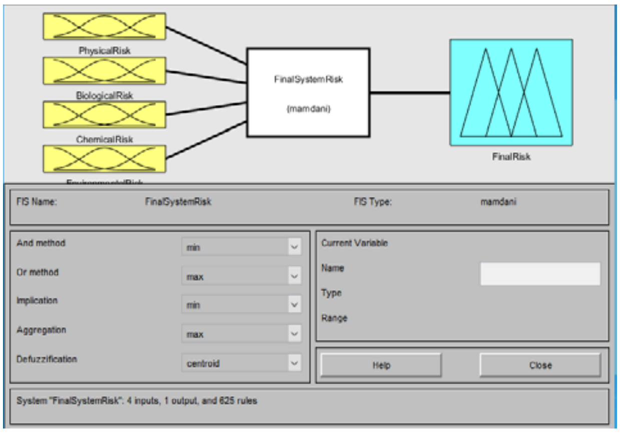

Fig. 3: Risk Analysis, final Mamdani FIS.

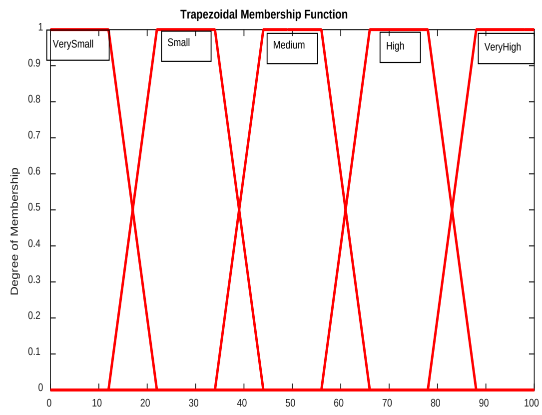

Fig. 4: Trapezoidal Membership Function

Each model of the first four FIS (Physical (P), Biological (B), Chemical (C), and Environmental (E) models) have three inputs (O, S, and D) and the final FIS has four inputs (P, B, C, and E) with one final output to form a cascaded system.

The inputs are fuzzified and go through the Fuzzy engine before being defuzzified to give a crisp output. The defuzzification method selected for this evaluation is the Centroid of Area, because of the even distribution of the expected probability values [3].

Trapezoidal MF (Fig. 4) can be briefly defined by *min* and *max* as thus;

$$trap(x;\alpha,\beta,\gamma,\delta) = \max\left(min\left(\frac{x-\alpha}{\beta-\alpha},1,\frac{\delta-x}{\delta-\gamma}\right),0\right) \qquad (1)$$

The equation is valid when $\alpha < \beta \leq \gamma < \delta$ is true.

The Fuzzy rules are generally expressed as "IF-THEN" rule and it could be extended to "IF-AND/OR-THEN" depending on the expert knowledge of the system. "IF-AND-THEN" ('AND' the fuzzy operator) was used to develop the proposed model rules for efficiency and accuracy.

The rule holds the learning as a course of action of guideline for the entire system. Fuzzy rules are developed through human knowledge and expert of the system. It is fair to say the more understanding of the system an expert has, the better the rules developed to solve issues related to that system, and this makes the proposed models suitable and reliable in analyzing and evaluating the risk level of the dairy products manufacturing.

Even though [4, 5] have argued the bias nature of giving criteria weight to failures by experts, which sometimes may not truly represent the true state or extent of the issues or failures, the proposed model will help reduce the effect of double standard (biases) in allocating weight to failures due to its novel approach of running each failure through different stages before prioritizing it.

This mechanism allows input of different sets from which the outputs are determined in the proposed model methodology. It analyses dairy products manufacturing systems for benchmarking, which reduces the cost of operation because of less second guesses in the operation. The proposed models result is general and applicable to any dairy products manufacturing systems if it is applied rightly with few tweaks to the rules.

II.A PHYSICAL RISK DEFINITION

The consequences of this physical risk expound greatly on the most condemnatory disaster and the remedial measures needed for a proper diminishment on the hazard that this failure presents. The examination of the physical risks instigated the criticality of the consecutive procedures of the dairy products to the customer. At whatever time, the workforce has contact with the raw milk or altered the procedure parameters without a doubt influences the final results. The major causes of the unwanted finished products are (1) absence of appropriate preparation; (2) corroded facility; (3) Personal hygiene; and (4) deficient dairy products manufacturing background.

II.B BIOLOGICAL RISK DEFINITION

The Biological risk is the second Mamdani FIS proposed model to analyze biological risk in dairy products manufacturing. Milk products conserve an assortment of microorganisms such as viruses (Cytomegalic and retroviruses) and microbes [11]. The authors in [12] discovered that the normal inhibitory frameworks in milk products keep a huge ascent in a microbial cell means the initial 3 or 4 hours at encompassing temperatures. It is vital to note that microorganisms can likewise navigate through numerous means; for example, when it is exposed to equipment, human, water, air, and so forth [13]. The following are examples of factors contributing to biological risk.

- Microbiological contamination due to an inconsistent temperature within the operation and the transportation of both raw or/and finished products.
- Pathogenic bacteria caused by lack of proper covers sealing practices.
- Improper handling of the raw milk during and after receiving contributions to the micro-organisms decay.

III.c CHEMICAL RISK DEFINITION

If not properly managed, the addictive or chemical used during the manufacturing processes could result in failures or risks to both the manufacturer and the consumers. The contaminants could be from the packaging materials, animal feeding, air and water chemistry discrepancy. A deliberate adulteration could also be a source of contamination.

II.d ENVIRONMENTAL RISK DEFINITION

The effect of carbon dioxide (CO_2) emission on the environment has been widely studied by many researchers and government agencies. The outcomes results have introduced many legislative and policies to regulate the greenhouse emission. The dairy products manufacturing industries are not exempted from these policies. Many organizations have been fined tremendously by the government for noncompliance; which had, in turn, instigated others into actions. The introduction of these policies in the last decades has caused a major facility restructure in numerous industries. Due to the nature of dairy products that need to be refrigerated throughout its lifespan, the disposal of the waste products during the extraction of milk and manufacturing etcetera shows the importance of the effect of environmental policies on dairy products manufacturing.

II.e INPUTS EVALUATION CRITERIA

In the FMEA approach, the criteria connected to model or evaluate a criticality of the failure mode of an item is the seriousness, severity or consequences of the failure impacts, its recurrence of the event (Occurrence), and the probability that the proposed solution will capture the envisaged failures when it happens. The interpretations and the ranking of the factors are based on expert opinion and knowledge and likewise the RPN analysis definition that has been adopted by many researchers.

The parameters are defined and ranked based on FMEA methodology to give equal weight to all the criteria. It is important to emphasize on the drawbacks of traditional FMEA. The traditional FMEA methodology uses the output of RPN (i.e. the product or multiplication of the Occurrence, Severity, and Detectability) to rank level of risk of a process (manufacturing or other processes), which is not appropriate since the different arrangements of the criteria will give the same results, with different risk consequences [9]. Traditional FMEA RPN approach ignores different opinions and ideas of the experts and performs better only in safety evaluation while depleting the quality and environmental impacts on the systems.

Table 1: Evaluation Criteria for the inputs

Rank	Linguistic term
0 - 19	Very Small
20 - 39	Small
40 - 59	Medium
60 - 79	High
80 - 100	Very High

The Table 1 indicates the variables for a linguistic term which defines the term factors and as well as the range to classify the level of the risk. The Table also serves as a reference point to define the membership functions for the proposed model. The range between 0 and 100 are used for easy understanding of the output result, so that each person can understand the results irrespective of their educational level or knowledge.

The model using the proposed arrangement of the fuzzy inference system will eradicate this shortcoming of the traditional FMEA RPN methodology.

II.g FUZZY RULES DEFINITION

The membership functions play a huge role in defining the fuzzy rules, this research work is not exempted. While the membership function is paramount to defining appropriate fuzzy rules, the experience, opinions, and knowledge of the expert ensure the rules perform the intended objectives without any sense of biases.

The rule base holds the learning as a course of action of guidelines for the entire system. Fuzzy rules are developed through human knowledge and expert of the system. It is fair to say the more understanding of the system an expert has, the better the rules developed to solve issues related to that system. And the inputs and outputs of a fuzzy inference system are dependent on the if-then rule set, even though [3] argued that the fuzzy rules might be not applicable in every application because they may not be accurate enough.

Fuzzy rules can be derived through numerous approaches. However, there are two widely used approaches [7]. These two approaches are mutually inclusive, which gives the most accurate approach to derive the fuzzy rule base [8]. The approaches are listed below:

- The opinion and knowledge of the experts
- The process of Fuzzy Mode.

These approaches were implemented in defining the fuzzy rules for the proposed models. As mentioned earlier, the expert's knowledge and opinions are directed to identifying the failure modes for each category and provided information on the occurrence, severity, and detectability of those identified failure modes.

The fuzzy rules for each failure category are little different due to several consequences that are associated with each failure mode.

As previously mentioned, a total of 1125 rules were developed, to solve these dairy products challenges and provide a better solution to currently adopted approaches that are marred with shortcomings. The fuzzy rules for physical, biological, chemical, and environmental risks follow the general pattern listed below:

If the Occurrence is Very Small and Severity is Very Small and Detectability is Very Small THEN the Risk is Minor.

If the Occurrence is High and Severity is Very High and Detectability is Very Small THEN the Risk is Very Important.

If the Occurrence is Medium and Severity is Very Small and Detectability is Very High THEN the Risk is Important.

If the Occurrence is Small and Severity is Very High and Detectability is Small THEN the Risk is Moderate.

If the Occurrence is Medium and Severity is Small and Detectability is Medium THEN the Risk is Low.

If the Occurrence is Very High and Severity is Very Small and Detectability is Very Small THEN the Risk is Moderate.

The proposed final FIS rules are based on the outputs of the above rules for each category to give a final dairy product manufacturing system risk ranking (final output).

II.h GRAPHICAL USER INTERFACES (GUIS) FOR THE PROPOSED MODELS.

The graphical user interfaces (GUIs) are designed to give a platform for easy entering of input data and perform extensive understanding. The Physical, Biological, Chemical, and Environmental GUIs allow the user to slide between Very_Small to Very_High as shown in Figs. 5 and 6 while the values are displayed to give crisp values, meaning no numerical data required to analyse the first four FISs proposed. The important aspect of that is that the users do not need to know the value; but users can slide within the variable (Very_Small, Small, Medium, High, and Very_High), and click on the button (Physical Risk, Biological Risk, Chemical Risk, and Environmental Risk) to get the output crisp value of the risk. Only the Physical and Biological risk GUIs are shown here; the other two GUIs follow the same structure. The GUIs were designed using MATLAB GUIDE [16].

The Final GUI indicates the final proposed FIS model designed to analyse risk level of the dairy products manufacturing system. The average risk level of each category (Physical, Biological, Chemical, and Environmental) is fed, to get a final score of the risk level of the manufacturing system. The Final GUI is different from the first four GUIs because it requires as inputs the crisp values derived from the outputs of the first four GUIs, to analyse the risk level of dairy manufacturing system as shown in Fig 7. These proposed models can be used as an audit tool within the organization to analyse the risk level of the manufacturing processes.

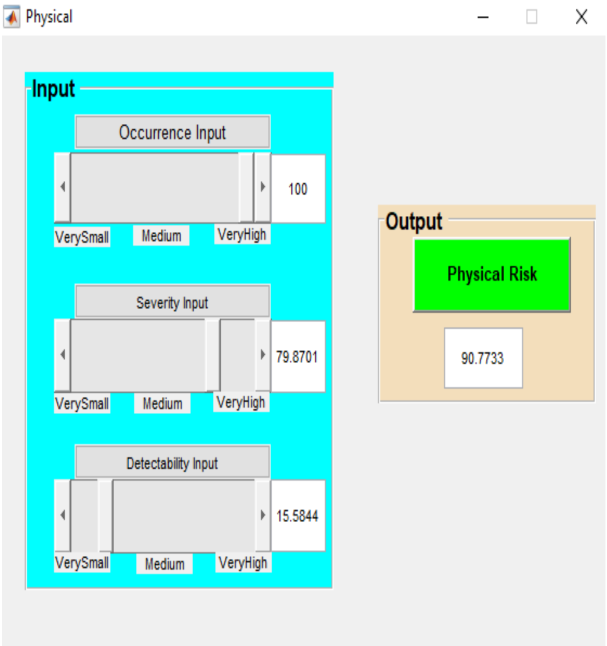

Fig. 5: Proposed Physical Risk GUI Model

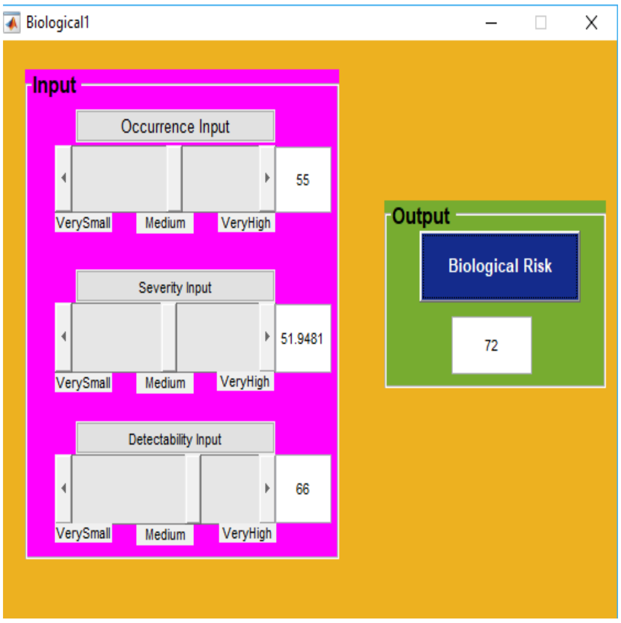

Fig. 6: Proposed Biological Risk GUI Model

Some other details on the GUI Models can be found in [16].

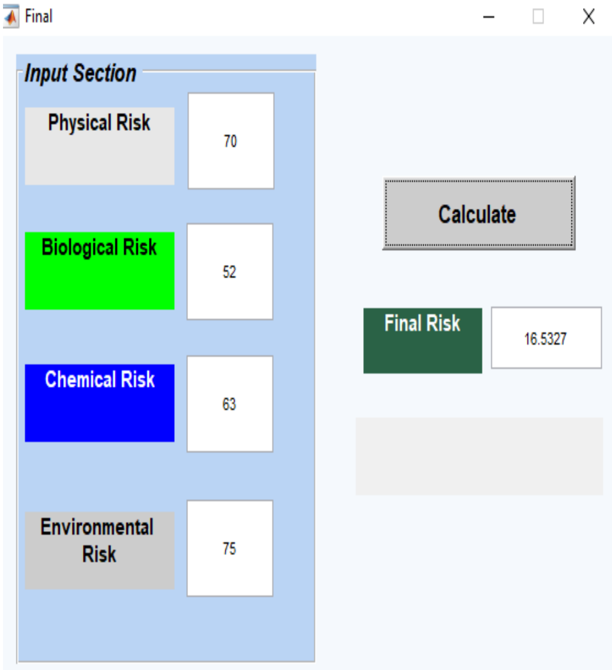

Fig. 7: Proposed Final Risk Assessment GUI Model

III.RESULTS

The finished products of dairy products pass through many processes to make it acceptable for the consumer. Thus, making the consumers the paramount element to consider during the processes.

Although many approaches have been explored to get to the root-cause of the failures associated with dairy products manufacturing that may affect the intent consumers (which cut across all generation due to dairy products nutrient benefits), this research analysed the risk of the failure modes in dairy products manufacturing. This study provides a well improved failure ranking, which will result in proper channelling of resources to the most important failures. This in turn will reduce operation cost, rework time, and extract information about risks to mitigate such failures in the future. But, most importantly the ranking will lead to yield safe dairy products to the consumers. The Occurrence, Severity, and Detectability were used as the fuzzy inputs to the first four FISs, to analyze the failure modes in each category (Physical, Biological, Chemical, and Environmental) and give outputs of each risk level. The outputs of the first stage were used as inputs to the second phase final FIS to rank the dairy products manufacturing system.

All the results are derived based on the proposed Mamdani FIS model using MATLAB Mamdani Fuzzy Inference Systems Toolbox. The experimental results of the proposed Mamdani FIS approach is compared with the traditional FMEA RPN. The ranking of the failure modes show a well reliable result since the knowledge of the experts is incorporated in the fuzzy rules. It is important that the parameters are optimised to give an accurate and reliable fuzzy set

Table 2: Proposed Physical risk output results versus FMEA RPN

Failure Modes	O	S	D	PR	FIS Ranking	FMEA RPN	RPN Ranking
PFM1	68	48	40	72	2	130.56	10
PFM2	60	55	45	59	8	148.5	5
PFM3	50	60	48	59	8	144	6
PFM4	82	40	70	68.8	4	229.6	2
PFM5	60	60	60	65.6	5	216	3
PFM6	30	75	40	50	13	90	13
PFM7	63	60	50	70.4	3	189	4
PFM8	55	60	20	59	8	66	14
PFM9	60	60	40	65.6	5	144	6
PFM10	50	50	55	50	13	137.5	8
PFM11	60	45	50	59	8	135	9
PFM12	50	80	70	74.7	1	280	1
PFM13	40	0	30	9.32	17	0	17
PFM14	48	30	28	28	16	40.32	16

Tables 2, 3, 4, and 5, show the experimental results versus FMEA RPN. The important point to notice is when one of the input criteria is zero (0) PFM13, the FMEA RPN methodology gives no risk as the output, but the proposed approach still recognised that there is a risk, though, the risk level is relatively small. This is one of the advantages of the proposed methodology over RPN.

Physical, Biological, Chemical, and Environmental Failure modes are represented with PFM, BFM, CFM, and EFM in Table 2, 3, 4, and 5.

From the results, the biological risk requires more attention because of the higher risk level compared to physical risk. Environmental risk also represents an area for improvement. The weighted average of the output results from the first stage was done twice before used as the inputs to the final stage to give a complete risk analysis of dairy products manufacturing. A comparison between two different organizations was performed to rank the organizations based on the risk level. Table 6 shows the result of the comparison using the proposed final FIS.

Table 3: Proposed Biological risk output results versus FMEA RPN.

Failure Mode	O	S	D	Biological Risk	FIS ranking	FMEA RPN	RPN ranking
BFM1	60	88	82	90.7	7	432.96	2
BFM2	40	90	70	90.7	7	252	9
BFM3	88	70	50	91.5	1	308	4
BFM4	40	80	44	66	16	140.8	18
BFM5	50	70	73	91.5	1	255.5	8
BFM6	75	70	62	90.7	7	325.5	3
BFM7	80	80	48	91.1	4	307.2	5
BFM8	55	60	40	59	20	132	19
BFM9	60	70	60	77.7	13	252	9
BFM10	60	60	40	65.6	17	144	17
BFM11	50	80	70	91.1	4	280	7
BFM12	40	60	65	68.8	15	156	15
BFM13	80	92	93	91.1	4	684.48	1
BFM14	68	70	60	90.7	7	285.6	6
BFM15	70	90	40	81.3	12	252	9
BFM16	70	70	30	91.5	1	147	16
BFM17	40	70	44	63	19	123.2	20
BFM18	60	72	50	77.7	13	216	13
BFM19	60	60	50	65.6	17	180	14
BFM20	70	80	40	84.5	11	224	12

Table 4: Proposed Chemical risk output results versus FMEA RPN

Failure Mode	O	S	D	CR	FIS ranking	FMEA RPN	RPN ranking
CFM1	60	80	65	87	6	312	2
CFM2	50	78	76	91.5	3	296.4	3
CFM3	40	70	90	90.7	1	252	5
CFM4	40	50	15	41	11	30	11
CFM5	38	75	60	65.6	7	171	7
CFM6	25	95	50	91.5	8	118.75	9
CFM7	57	70	40	73.7	9	159.6	8
CFM8	30	65	40	46.7	9	78	10
CFM9	50	80	70	91.1	5	280	4
CFM10	40	75	80	81.4	2	240	6
CFM11	68	80	73	91.1	4	397.12	1

The final FIS result is interpreted in an opposite way to the first four FISs. The lower value means a bad manufacturing system, while higher output value indicates the best manufacturing system. From the experimental results, some recommendations are made to mitigate or reduce the risk level of each category. Some of these countermeasure actions are listed below;

- Raw milk must be investigated and analyzed periodically for possible microorganism contamination
- Develop a standard operating procedure for maintenance and ventilation control
- The water treatment should be occasionally done to reduce micro-organism,
- Develop a farmer education system to educate the farmers on the dairy animal management,
- Standardize the regulating parameters (pneumatic, pressure, temperature) with the visual control for easy identification once it's out of scope,
- Implement a standardized maintenance tool to uncover any deviations in the manufacturing processes etc.

IV CONCLUSIONS

The objective of this work is to develop an intelligent system capable of analyzing and evaluating risks in dairy products manufacturing systems. The traditional risk assessment strategies manage deficient or ambiguous data due to inadequate knowledge of the system and no involvement of the experts in the risk assessment. Also, they lack of an obvious inner failures system to furnish experts with an accurate and dependable risk ranking.

The proposed intelligent system composed of a set of five well connected FIS (Mamdani) is capable of managing the shortcomings of traditional risk assessment strategies and incorporate the expert opinions into the mechanism to give reliable outcomes. To navigate through these hurdles, a robust model of five Mamdani Fuzzy Inference System has been proposed and developed. The models were tested with experimental data to provide the model's verification and insight on how the model works.

One of the advantages of this approach is to enable industries to benchmark on a good working manufacturing system with lower risk level for the betterment and improvement of the systems with higher risk level.

For consolidated consensus methodology for the probabilistic assessment of safe operation, benchmarking practices have been proven to be exceptionally effective [6]. Not only will this model be a handful for benchmarking, it is also a reference point to every dairy product manufacturer.

Table 5: Proposed Environmental risk output results versus FMEA RPN

Failure Mode	O	S	D	ER	FIS ranking	FMEA RPN	RPN ranking
EFM1	65	70	60	87	3	273	2
EFM2	40	85	10	64.4	6	34	7
EFM3	70	80	60	90.7	1	336	1
EFM4	40	50	20	50	7	40	6
EFM5	80	60	45	77.7	4	216	3
EFM6	75	70	40	90.7	1	210	4
EFM7	70	40	25	72	5	70	5

Table 6: Experimental final output dairy products manufacturing systems risk of company A versus (Vs) B ranking.

Final Result Company "A" Vs Company "B"		
Categories	Company A	Company B
Physical Risk	59.6	44
Biological Risk	81	51.2
Chemical Risk	77.4	28
Environmental Risk	76.1	56.3
Final Output Result	9.23	49.2

The experimental results of the models provide an insightful outlook on how to reduce risk level in each category (Physical, Biological, Chemical, and Environmental) to propel more effective dairy products manufacturing processes and to increase the operation productivity. The biological and environmental failures have the highest and higher risk respectively and the results also suggest the most important areas to allocate resources to reduce the risk level.

The Mamdani Fuzzy Inference System models have been proposed and designed to accurately analyze risk level of dairy products manufacturing systems. The proposed models are found to provide more reliability and easy to understand results. These proposed models also incorporated expert's opinions and use real manufacturing methodologies to assess the common failure modes in dairy products manufacturing. The Mamdani Fuzzy MATLAB Toolbox was used to develop and analyse these proposed models.

A great understanding of the use of GUIDE GUI in this research facilitates a significant improvement on huge time consumption while using fuzzy variables and memberships functions with thousands rules and still returning results quickly. So, for industrial use of a Fuzzy Inference ystem in a large project; a recommendation is made for an incorporated GUIDE GUI that would give a great and faster implementation.

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