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An Integrated Approach of QFD and TPM in an Indian Meat Product Manufacturing Facility

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Abstract-- Quality Function Deployment (QFD) is a tried and tested method which ensures proper translation of the needs and demands of the customer into corresponding engineering attributes that can be easily incorporated into the design process. The methodology will also serve in properly refining the process in a continuous manner, helping the company adapt to the ever-changing voice of the customer (VOC). In short, QFD sets effective development targets for enhanced product and service characteristics.In spite of its multifarious advantages, the food industry appears uncertain of adopting it. This study aims to break into this formerly uncharted area, with an integrated QFD and TPM analysis on a meat product industry. Based on the inferences derived from the subsequent HoQ, the study arrives at several strategic areas for development. While some of these can be decided upon independently, most decisions are to be taken only after being fed into the TPM module.Owing to its high sales volume, pork sausage is the product under study.

Keywords-- Quality function deployment (QFD); Total productive maintenance (TPM); Sausage manufacturing; House of quality (HoQ)

I INTRODUCTION

Engineering design is an art. A good design circumscribes every aspect related to the job, even accounting for the ever-evolving needs and demands of the customer. It can even be said, in a sense, that the voice of the customer (VOC) forms the base from which a good production engineer begins his design. Be warned though, the process might appear cumber some at first, and many real-time changes might have to be accommodated. After all, customers have become all the more selective and demanding in their pursuits. Rest assured, it is worth the trouble.

The Kerala State Animal Husbandry department pegs the state's daily consumption of meat at almost 5,000 tonnes. The sheer volume alone begs our case for an analysis on whether there is room for improvement in the Quantity and Quality departments of the meat being dealt. QFD is a well established and powerful tool [7, 3, and 6] in this regard, especially since such an analysis has missed the attention of many a mind. Through this study, we hope to investigate the prospective benefits to the customer by subjecting pork sausage production to an integrated QFD and TPM study.

II ABOUT THE COMPANY

The company selected for this study is an Indian meat product manufacturing industry called Meat Products of India Ltd (MPI). It is a public sector company undertaken by the Government of Kerala, India, established in 1973. With a category A No.1 license from the Ministry of Food Processing Industries (Government of India), MPI engages in the manufacturing and marketing of meat and its allied products. In addition to sourcing meat from young and healthy livestock, MPI makes it a point to employ only but the latest manufacturing technology, which ensures proper hygiene in the workplace, longer storage time and a higher nutritional value for the final product.

The company deals in a variety of meat – beef, buffalo, pork, mutton, rabbit and the regular poultry. The processed and semi-cooked products include corn beef, meat loaf, sausages, curries, bacon, ham, cutlet-mix, chicken-n-ham and salami. Sausages, one of the most popular of the MPI products, come in varieties such as cocktail sausage, pork sausage, chicken pepperoni sausage and masala sausage. The products are available at all leading supermarkets and cold storages throughout Kerala and even other states. The company is selling 30-35 tonnes of meat products per month and uses the latest packing technologies like vacuum packing, plate freezing etc.

III MEAT SAUSAGES

Sausages go a long way back. It's origins have been traced to the Greek and Roman times, during when making sausages was a way to preserve leftover meat. The term itself is derived from a Latin word 'salsus', meaning 'salted'. Salting is an essential part since this prevents the meat from rotting, while at the same time helping it retain its flavor and shape.

Sausages come in all shapes and sizes. Pork, beef or chicken are the most favored. These are minced or processed, and filled in casings of animal intestines. Lately though, synthetic casings are also being used.

IV TYPES OF SAUSAGES

Popular varieties of sausages are listed below:

- Frankfurters – Cooked sausage popularly known as hot dog.
- Dried/smoked sausage – Contains cured, smoked and dried meat of pork or beef.
- Salami – Usually smoked. Sold in round slices.
- Italian sausage – Coarse pork meat with fennel and spice flavoring.
- Pepperoni – Lightly spiced with pepper. Mainly used as pizza topping.
- Liver sausage – Ground liver of pork, seasoned with spices.

V STUDY PHASE

The implementation study was carried out in three phases. The actions carried out under each phase is described in the following subsections.

Phase 1 – Data collection (Getting customer language)

In the first phase, customer requirements or VOCs were collected. For MPI, this meant handing out a structured questionnaire (figure 1) to the various distributors this company supplies meat sausages to. Their responses were gathered and recorded as inputs of HoQ [9].

Phase 2 – Technical Data collection

In this phase, technical solutions for the data collected in the previous step was sought. This involved interviewing and holding discussions with production managers and shop floor workers, with a view to gather insight on the technical solutions possible. This preliminary data is then observed and their correlation with various technical languages are established.

Data collected was then used to arrive at the corresponding HoQ (figure 2).

Phase 3 – Suggestions for implementing technical remedies through TPM

As a result of the steps so far, the HoQ matrix now yields a prioritized list of technical requirements. Implementing these outputs, either directly or through the TPM pillars, was made after consultations with the General Manager. Decisions were made based on the easiness and cost effectiveness of the implementation.

VI HOUSE OF QUALITY CONSTRUCTION

As a preliminary step, the customer languages were identified by discussing with the production manager. It was then decided to rank them based on customer feedback. This was arrived at by distributing an intelligently prepared questionnaire [4,11and 8] to some end users and dealers associated with MPI. A total of three dealers and seven end users were approached [1].

The questions were structured in Likerts scale of 0 to 10, with 0 representing the worst and 10 representing the best rating. The sum of the individual scores was used as the basis for the ranking system. It goes without saying, [12] a higher score would transform to a better rank.

The VOCs were converted into appropriate technical language [3, 5] after long discussions with the technical and quality managers at MPI. The various technical aspects were found out and attributed weightages, in order to quantify them. The symbols used to depict the various relations and their scores are given in the Table 1[10]. Using these data, customer technical interactive scores and correlated scores of technical languages were calculated [13].

Customer technical interactive calculations were done as follows:

Formula

$$\text{Customer interactive score} = \sum_{i=1}^{n} (\text{Relationship values between customer voice and Technical languages}) \times (\text{Expected values of customer voice})$$

Where *n* refers to the number of customer voices.

Example

Customer technical interactive score for ‘maintain spice content’=

9 x 42+ 9 x 12 + 1 x 55 + 9 x 49 + 9 x 34 +9 x 53 + 3 x 34 +

1 x 16 + 3 x 21 + 3 x 95 + 1 x 86 + 3 x 95 + 1 x 0 + 3 x 96 = 2890

In order to visualise the relative weightages, the percentage normalised value of customers technical interactive scores were computed as follows.

Formula

$$\text{Percentage normalised value of customer's technical interactive score} = \frac{\text{Customer technical interactive score}}{\text{Sum of customer technical interactive score}} \times 100$$

Example

Percentage normalised score of customer's technical interactive score against the technical voice 'Maintain spices content' = (2890 /103523) 100 = 2.8

These computed scores are displayed in Table 2. The weighted correlated value is calculated by summing the values of correlations. As shown in Figure 2, the weighted correlated value against the technical parameter 'Maintain spices content' is 114.

In order to visualise the relative scores of technical correlation, the percentage normalised value of correlated weightages were calculated using the following formula:

Formula

$$\text{Percentage normalised value of correlated score} = \frac{\text{Correlated score of the technical language}}{\text{Sum of correlated score}} \times 100$$

Example

Percentage normalised of correlated score against the technical parameter '*Maintain spices content*'

= 114 /6685 x 100 = 1.7

Both percentage normalised score of customer's technical interactive score and percentage normalised value of correlated score have been added and entered in the side of correlation matrix of HoQ and are termed as total normalised values. They are given in the Tables 2. All these values were used to construct the HoQ matrix, which is depicted in Figure 2.

VII **IMPLEMENTATION OF TECHNICAL REQUIREMENTS**

The outputs of the QFD matrix [2] are found out, and analysed. After an in-depth discussion with the production manager, several strategic decisions, with respect to whichever technical languages [13] need to be subjected to TPM, are made. For the ones exempted from being fed into the TPM pillars, action plans are in place, as shown in Table 3.

From the QFD matrix, the sum of percentage normalized score of customers technical interactive score against the technical voice, and that of the percentage normalised value of correlated score (N1+ N2) against 'Better testing procedure' and 'Control water content', are 8.5 and 8.2 as shown in graphs 3 and 4 of figure 3. It is apparent from the values that these are the most important factors which need to pass through the TPM hoop. Complete analysis can be found in Table 6.

Better testing procedure

While endeavoring to take on a task with so many variables, it is only imperative that testing be done at each stage, in addition to the after-production stage. Table 4 shows the recommended action at each stage.

As a practice, it is always best if a target value is set taking into consideration all the variables, like the seasoning time, preservatives, bacteria count, climatic conditions, pH value of meat, curing time, temperature control, water control, smoking time, smoke density etc.

Control water content

The importance of controlling water content in sausages cannot be stressed on enough. Excess water will affect the drying time, seasoning time, texture, odor, pH value, flavor etc. It also leaves the meat vulnerable to bacterial spoilage and poses some serious problems to the packing department (vacuum packing, especially).

VIII **RESULTS AND DISCUSSION**

In a country like India, where most states impose invisible bans on the sale or consumption of bovine meat, Kerala is an exception. As a major consumer of meat and allied products, this state is a perfect place to carry out such an analysis. The absence of a similar analysis on the meat production industry is yet another reason which forced the research in this direction.

The method adopted for QFD ensures that all aspects of the product, right from customer requirements to production realities, are taken into account. Suffice to say, QFD is a powerful tool for assessing the quality of a product.

To carry out the study, the questionnaire was prepared in such a way that it took into consideration a host of factors – sensorial to tactile to perceptive characteristics. This was then distributed to gather the differing voices of customers. After a careful analysis of the feedback, the House of Quality was built.

IX **CONCLUSION**

The sausage production facility of MPI was subjected to an integrated QFD and TPM study. The recommendations of the study have been explored at length; though making changes to the status quo is often hard. QFD is an ideal tool to evaluate the 'Customer's Voice' and thereby improve the efficiency and output of a process, but for results to be evident, the cooperation of the staff and management of the production facility is of utmost importance.

While the experimenters do think the study has gone in the right direction, the monetary implications and the mindset changes implied in the recommendations cannot be achieved overnight. It will need time to sink in. That said, the MPI management is yet to take a call on the physical changes to be made at the facility, as this mostly involves the aforementioned monetary considerations.

Changing the employee mindset is harder. Proper education and training, followed by some prodding by managers, can work wonders. Without this, however, the workforce will think of it as yet another burden the management has deftly passed onto their shoulders.

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Table 1
Symbols used in QFD matrix

Relation	*Symbol*	*Score*
Strong	□	9
Moderate	△	3
Weak	○	1

Table 2

TECHNICAL DESCRIPTORS AND THEIR COMPUTED SCORES

S.NO	*Technical Descriptors*	*Customer Technical Interactive score* (1)	*Percentage normalized value of customers technical interactive score* (2)	*Correlated weightage of the technical language* (3)	*Percentage normalised value of correlated weightage* (4)	*Sum of* (2)+ (4)

1	Maintain spices content	2890	2.8	114	1.7	4.5
2	Maintain salt content	2202	2.1	157	2.3	4.4
3	Adequate seasoning time	3858	3.7	165	2.5	6.2
4	Proper mixing of ingredients	3558	3.4	127	1.8	5.2
5	Use of preservatives	4618	4.5	191	2.9	7.4
6	Proper weighing methods	1260	1.2	147	2.2	3.4
7	Regulate fat content	4154	4	183	2.7	6.7
8	Protein content	1902	1.8	121	1.8	3.6
9	Age of animal	3303	3.2	100	1.5	4.7
10	Meat part used	3626	3.5	155	2.3	5.8
11	Bacteria count	3185	3	186	2.8	5.8
12	Climatic conditions	4320	4.1	168	2.5	6.6
13	Lowering the PH	865	0.8	118	1.8	2.6
14	Curing time	970	0.9	170	2.5	3.4
15	Selection of casings	2433	2.3	141	2.1	4.4
16	Proper temperature control	4595	4.4	160	2.4	6.8
17	Control water content	5471	5.3	196	2.9	8.2
18	Control smoke density	2414	2.3	142	2.1	4.4
19	Control smoking time	2477	2.4	150	2.2	4.6
20	Good mechanical strength	774	0.7	95	1.4	2.1
21	Feasible price setting	447	0.4	168	2.5	2.9
22	Packaging form	2232	2.2	186	2.8	5
23	Packaging size	1590	1.5	155	2.3	3.8
24	Degradable material	968	0.9	139	2.1	3
25	Light weight material	330	0.3	166	2.5	2.8
26	Attractive Labeling	2196	2.1	65	0.9	3
27	Odorless material	674	0.6	83	1.2	1.8
28	Hot & Cold temp resistant	662	0.6	164	2.5	3.1
29	Resistance to OIL & FAT	1178	1.1	150	2.2	3.3
30	Sealing capacity	1770	1.7	194	2.9	4.6

S.NO	*Technical Descriptors*	*Customer Technical Interactive score (1)*	*Percentage normalized value of customers technical interactive score (2)*	*Correlated weightage of the technical language (3)*	*Percentage normalised value of correlated weightage (4)*	*Sum of (2)+ (4)*
31	Packaging design	2390	2.3	249	3.7	6
32	Show freezing methods in the pack	1857	1.7	136	2	3.7
33	Show nutrition facts in the pack	1857	1.7	103	1.5	3.2
34	Better testing procedure	4444	4.3	278	4.2	8.5
35	Better inspection of raw material	4908	4.7	225	3.4	8.1
36	In process inspection	3430	3.3	205	3.1	6.4
37	Unit operation control plan	3086	2.9	184	2.8	5.7
38	Employee Awareness	3455	3.3	263	3.9	7.2
39	Control material wastage	1577	1.5	139	2.1	3.6
40	Maintain uniform sausage size	2400	2.3	144	2.2	4.5
41	Convenience of packing	474	0.4	131	1.9	2.3
42	Convenience of storing in the shelf/ freezer	1064	1	125	1.9	2.9
43	Include different sausage recipes in the pack	1659	1.6	47	0.7	2.3

TABLE 3 SOME OF THE TECHNICAL LANGUAGES WHICH NEED NOT PASS THROUGH TPM

TECHNICAL LANGUAGES	ACTION PLAN
Protein content	Protein content depends on the amount of calories advised in a person's diet, to support his/her activity level. Protein should account for 10 to 35 percent of the total calories. Based upon the sausage ingredients, generally 12.8gm of protein is advised for 100 g of serving size.
Lowering the PH	As per the manual of Food Safety and Standards Authority of India (FSSAI), the typical pH value of pork sausage is normally (4.8-6). Higher pH values are desirable for better water holding capacity, juiciness and other sensory parameters. A digital pH meter can give accurate readings. Values are taken by the direct contact between the sensitive diaphragm of the electrode of the pH meter and the meat tissue.
Feasible price setting	Pricing for the sausages should be affordable and reasonable. Prices are set by a firm by taking into consideration factors like costs, profit targets, competition and perceived value of products. Prices are also affected by various tax liabilities which a company and the product is subjected to. It includes, excise duty, sales tax and local taxes etc.
Temperature resistant packing	The basic purpose of packaging is to protect meat and meat products from undesirable impacts on quality, including microbiological and physio-chemical changes. For sausages, semi-automatic vacuum- packaging can be employed. A bottom film is moulded according to the shape of the sausages by using heat and force (by compressed air or mechanical). These machines are called thermo-formers. The sausages are loaded and a rigid top film is sealed on after evacuating the moulded spaces. Individual product portions are cut apart along their sealing layers.
Resistance to OIL & FAT packing material	Grease proof paper (made of heavily beaten pulp), glassine and vegetable parchment materials can be used as packing materials. These are fat, oil and odour resistant materials with high wet strength and non toxic.
Degradable Packaging material	Waste disposal is a major issue with plastic packaging. Conventional synthetic polymers from petrochemicals are not biodegradable. These are a significant source of environmental pollution, damaging the organic characteristic of our surroundings. The row materials such as fossil fuel and gas could be partially replaced by greener agricultural sources, which should also contribute to the reduction of CO2 emissions. Polylactate (PLA) is a biodegradable polymer which can be a good alternative.

TABLE 4 ACTION PLAN RECOMMENDED IN TPM PILLARS FOR **'BETTER TESTING PROCEDURE'**

BETTER TESTING PROCEDURE	ACTION PLAN
Autonomous maintenance	Better testing methods should be followed for raw material selection, sensorial characteristics, tactile characteristics, packaging etc. Routine testing procedures has to be made mandatory during the time of production and after. Cleaning and maintenance of the equipment should be done by equipment operators.
Individual improvement	Workers should able to observe the values/readings from the instruments accurately.
Planned Maintenance	A calibration schedule of instrument has to be made for daily, weekly, monthly, quarter-yearly and yearly. Calibration schedule has to be done such that it will not disturb production and testing.
Quality maintenance	Use fine raw materials without any compromise in quality.
Initial control/ Development Management	Testing instruments should be precise and accurate. A target value has to be made such that it controls the seasoning time, preservatives, bacteria count, climatic conditions, pH value of meat, curing time, temperature control, water control, smoking time and smoke density etc.
Education and training	Some equipment familiarization programmes have to be given to the equipment operators. Such training will make them capable of handling the equipment.

Office TPM	Better testing procedures can be achieved by digitizing the testing methods and labs. Use of modern instruments will impart precision and accuracy.
Safety, health and environment	Give adequate importance for safety, health and environment. Conduct awareness class for health and safety. Always use personnel protective equipments while conducting testing.

TABLE 5 ACTION PLAN RECOMMENDED IN TPM PILLARS FOR **'CONTROL OF WATER CONTENT**

CONTROL WATER CONTENT	ACTION PLAN
Individual improvement	The workers should able to know the permissible amount of water allowed in the sausage. Water content in sausage can be controlled by giving proper cuts, and adding sufficient amount of salt into meat.
Quality maintenance	Selection of the meat part, and the age of animal used is an important factor. Some meat parts contain muscle and fat rich in water. This should be controlled.
Initial control/Development	Excess water content will affect the binding of sausage, drying time, seasoning time, texture, odor, pH value and management flavor etc. water content in meat is not desirable for vacuum packing. If water persists, there is a chance microbial spoilage.
Education and training	Training on sausage making has to be given to the equipment operators. Such training will make them capable of controlling the amount of ingredients added.
Office TPM	Better testing and inline inspection procedures should be implemented. By means of modern instruments and techniques, the order receiving, scheduling of production and maintenance can be done fast.

TABLE 6 MAJOR ACTIVITIES WHICH ARE IMPLEMENTED BY PASSING THROUGH TPM

ACTION PLAN RECOMMENDED IN TPM PILLARS FOR '*MAINTAIN SPICES CONTENT*'

MAINTAIN SPICES CONTENT	ACTION PLAN
Individual Improvement	The workers should able to decide the correct quantity of spices while mixing.
Quality maintenance	Use fine and properly dried spices.
Education and training	Some training on sausage making has to be given to the equipment operators. Such training will make them capable of controlling the amount of ingredients added.
Safety, health and environment	Give adequate importance.

ACTION PLAN RECOMMENDED IN TPM PILLARS FOR '*MAINTAIN SALT CONTENT*'

MAINTAIN SALT CONTENT	ACTION PLAN
Individual improvement	The workers should able to decide the correct quantity of salt to be added into the mix.
Quality Maintenance	Use fine and ample salt. Salt reduces the amount of available water (which allows for preservation or shelf-life extension), extracts the meat myofibrillar proteins needed to make the product bind and to emulsify fat, and for flavor enhancement.
Education and training	Some training on sausage making has to be given to the equipment operators. Such training will make them capable of controlling the amount of ingredients added. In general, salt is added at a concentration of 1% to 2% (w/w) of the total sausage batter weight.
Safety, health and environment	Give adequate importance.

ACTION PLAN RECOMMENDED IN TPM PILLARS FOR 'ADEQUATE SEASONING TIME'

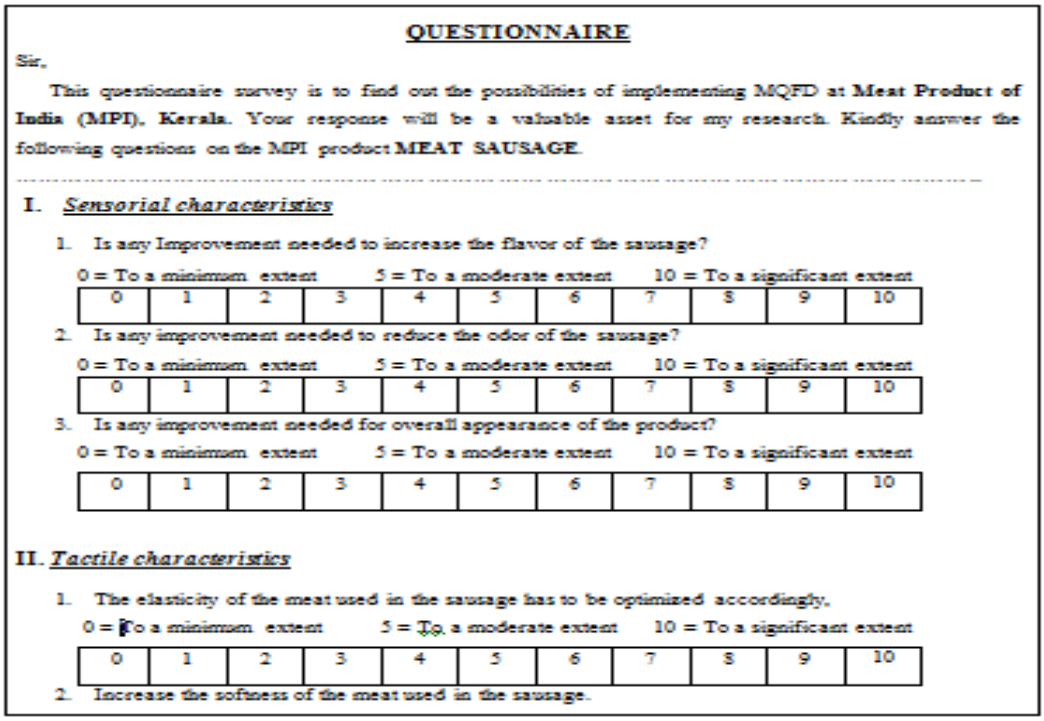
ADEQUATE SEASONING TIME	ACTION PLAN
Individual improvement	The workers should aware about the different seasoning techniques and seasoning time to achieve good texture and colour.
Planned maintenance	Time measuring instruments needed periodical check.
Quality maintenance	Use good raw materials, set correct seasoning time.
Education and training	Some training on 'sausage making' has to be given to the workers. Such training will make them capable of setting the correct seasoning time.

ACTION PLAN RECOMMENDED IN TPM PILLARS FOR 'PROPER MIXING OF INGREDIENTS'

PROPER MIXING OF INGREDIENTS	ACTION PLAN
Autonomous maintenance	Operators should inspect all machine components to make sure that they are in good condition. Actions have to be taken to prevent any damage to the components.
Individual improvement	Workers should be aware about the quantity of different raw materials to be added and the mixing time. Also they should be aware of the texture to be achieved. This is because mixing of ingredients affects the texture.
Planned maintenance	A schedule of inspection has to be made for the daily, weekly, monthly, quarter-yearly and yearly inspection of equipments. Production schedule has to be done such that it will not disturb production and maintenance.
Quality Maintenance	Use good raw materials, set correct mixing time.
Education and training	Training on 'sausage making' has to be given to the workers. Such training will make them capable of preparing good sausage mix.

ACTION PLAN RECOMMENDED IN TPM PILLARS FOR 'USE OF PRESERVATIVES'

USE OF PRESERVATIVES	ACTION PLAN
Individual improvement	The workers should aware about the quantity of preservatives added to the sausage mix.
Quality Maintenance	Preservatives are used to impact the color, minimize rancidity or to inhibit microbial growth. Examples of these are sodium nitrite, phosphates and sodium erythorbate. Nitrite is used for curing meat. It inhibits the growth of pathogenic and spoilage microorganisms.
Initial control/development management	Preservatives are permitted in sausage products, but under strict conditions and legal limits. Permitted preservatives can only be used.
Education and training	Training on 'sausage making' has to be given to the workers. Such training will make them capable of using preservatives safely.
Safety, health and environments	Employee safety has to be given utmost importance. Use proper safety measures while handling the preservatives. The preservatives must also be harmless to the environment.



QUESTIONNAIRE

Sir,

This questionnaire survey is to find out the possibilities of implementing MQFD at **Meat Product of India (MPI), Kerala**. Your response will be a valuable asset for my research. Kindly answer the following questions on the MPI product **MEAT SAUSAGE**.

I. *Sensorial characteristics*

1. Is any Improvement needed to increase the flavor of the sausage?

0 = To a minimum extent 5 = To a moderate extent 10 = To a significant extent

0	1	2	3	4	5	6	7	8	9	10

2. Is any improvement needed to reduce the odor of the sausage?

0 = To a minimum extent 5 = To a moderate extent 10 = To a significant extent

0	1	2	3	4	5	6	7	8	9	10

3. Is any improvement needed for overall appearance of the product?

0 = To a minimum extent 5 = To a moderate extent 10 = To a significant extent

0	1	2	3	4	5	6	7	8	9	10

II. *Tactile characteristics*

1. The elasticity of the meat used in the sausage has to be optimized accordingly.

0 = To a minimum extent 5 = To a moderate extent 10 = To a significant extent

0	1	2	3	4	5	6	7	8	9	10

2. Increase the softness of the meat used in the sausage.

FIGURE 1
EXCERPTS OF QUESTIONNAIRE ASKED DURING PHASE 1

Relation	*Symbol*	*Score*
Strong	□	9
Moderate	△	3
Weak	○	1

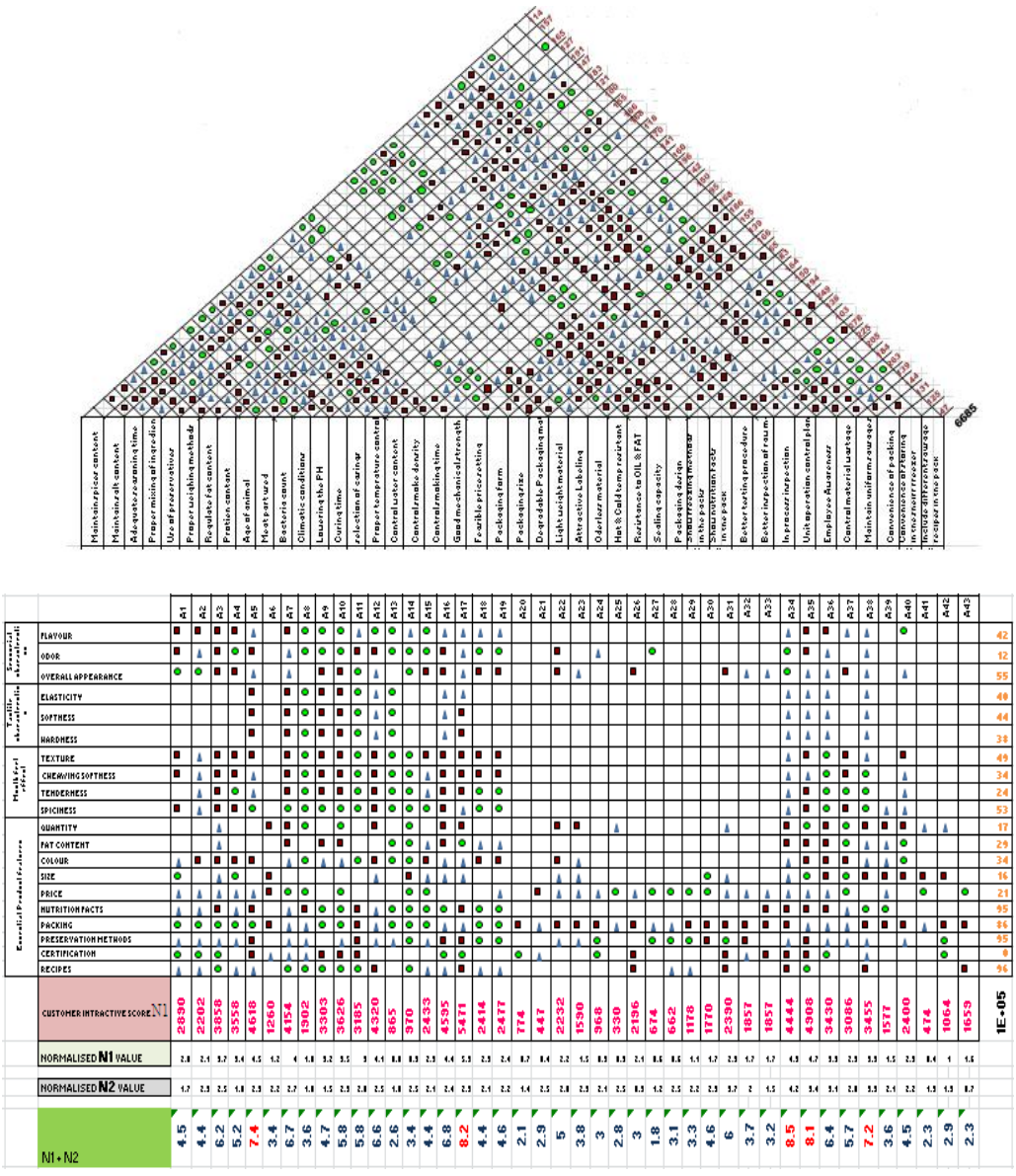
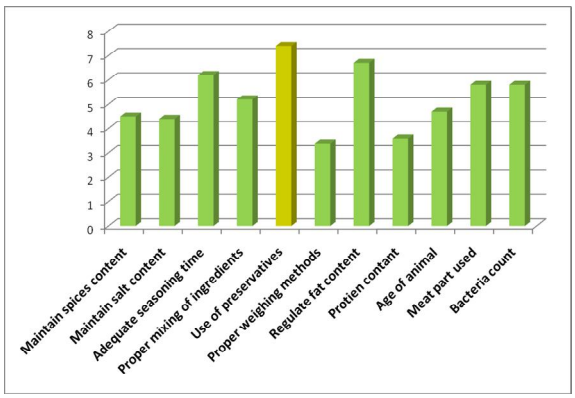


FIGURE 2 HOQ MATRIX



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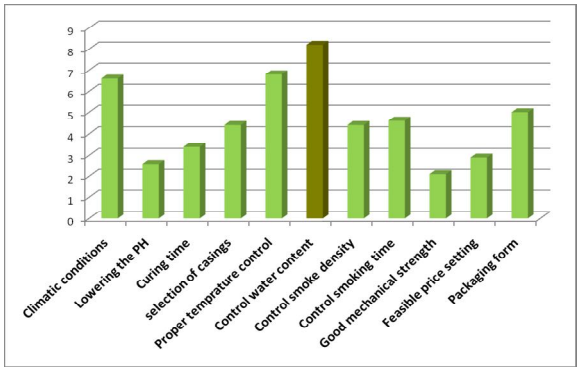

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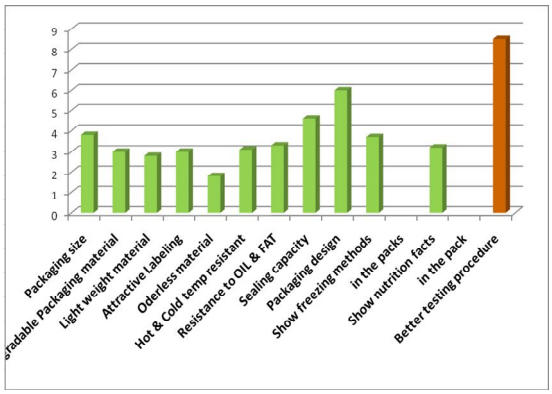
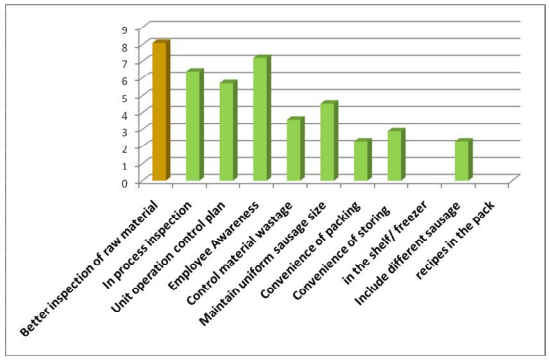


(3)



(4)

FIGURE 3
(N1+N2) GRAPHS

