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Integration of Quality Function Deployment (QFD) and Fuzzy Theory Model for Improving Quality of Cassava Opak Chips

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ABSTRACT

The cassava (Manihot Utilissima) can be processed into many kinds of processed cassava, one of them is the cassava Opak chips. The cassava Opak chips is a traditional snacks similar with the most popular crackers, made of a tasty, round and thin, boiled cassava. The cassava chips, for all this time, become the source of living for the community of processed cassava include another processed cassava. This business classified as home industry because it's production processed individually in each producer's home. In the home industries or small industries, the cassava Opak chips production processed manually with the quality product which hasn't meet the standard of food quality and customer needs. Therefore, need to do the cassava Opak chips quality improvement so they can produce the snacks. The cassava Opak chips made of cassava which can give the attraction and the quality warranty to the consumer. This observation aims to designing the cassava Opak chips product which has the certain quality based on consumer needs and wishes with the Integrated *Quality Function Deployment (*QFD) Method and Fuzzy Theory. This observation performed by interviewing the consumer, the Voice of Customer forming, questionnaires distribution, GAP calculations, technical characteristics determination, the House of Quality matrix making, draft concepts development, part specification determination, Part Deployment matrix making, and visualization design. Based on the result of the processed data on first and second iteration on QFD, we can get the technical classification and specification part, also recommendation to improve the cassava Opak chips product's quality.

Keywords: Cassava Opak chips, QFD, voice of Customer, fuzzy theory

PRELIMINARY

Opak (Cassava Chips) is one of the foods made from cassava. In home industry or small scale industry, opak (cassava chips)'s processed manually with quality that has not met the food quality standards and customer needs yet. Therefore, it is necessary to improve the quality of Opak (Cassava Chips) to create Opak (Cassava Chips) that can give attractiveness and quality assurance to consumers. The success of a product developed depends on the response of consumers. Product development results are said to be successful when getting a positive response from consumers followed by the desire and action to buy the product. Identifying consumer needs is the earliest phase in product development, because it determines the direction of product development (Karsak, 2004b).

One way to improve product quality is to know the customer's expectations and perceptions of Cassava Opak (Cassava Chips) products. In improving the quality of these products, it takes feedback from consumers Opak Cassava in the development of product quality to suit the needs and desires of consumers. The method that can be used in quality development is the Quality Function Deployment (QFD) method. QFD method is

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chosen because it is based on the needs and desires of customers and not only serves as a tool of quality, but also as a tool of planning a product in making improvements, so that strategic steps resulting from this research will provide more customer satisfaction (Tan, Xie, & Chia, 1998)

The quality of a food product is very important for every founder of food selling companies, food quality is a quality characteristic of food accepted by consumers (Rahman & Baksh, 1997). These include external factors such as size, shape, color, consistency, texture, and taste. There are nine factors that affect the quality of food, that is: Color, Appearance, Portion, Shape, Temperature, Texture, Aroma, Level of maturity, Flavor.

LITERATURE REVIEW: QUALITY FUNCTION DEPLOYMENT

Quality function deployment (QFD) that is well-known as a powerful method in the product design and development has been employed successfully in many manufacturing industries. This approach is driven from the customer needs that would be transformed into high characteristics of products. Karsak highlighted that the QFD is a customer-oriented design tool for integrating many cross functional aspects of organisation like marketing, design engineering and manufacturing in order to develop and improve quality products to enhance customer satisfaction (Karsak, 2004b).

The concept of quality function deployment (QFD) is developed to consider the quality at early stage of the design process. (Tan et al., 1998) mentioned that QFD is for clearly understanding and applying both engineering and management. (Rahman & Baksh, 1997) mentioned that the application of QFD method has been conducted successfully in both improving quality of existing products and developing new products.(Kumar & Antony, 2006) highlighted that QFD is a powerful approach to achieve the customer satisfaction by responding to the customer needs and doing benchmark to optimize the process, to improve the output value and also to minimize the use of resources. (Celik, Cebi, Kahraman, & Er, 2009) pointed out that this approach is a systematic concept to establish and translate the customer needs into product development including product planning, engineering and manufacturing. (Kannan, 2008) mentioned that QFD is a powerful approach for product design and development by planning and realizing the quality of products that would meet the customer expectations.

The application of the QFD has been conducted widely for the competitive product or service quality. Customer needs commonly relate to the performance of the product or service such as quality, cost, the availability, durability and time delivery. Basically, the qualitative research should be conducted properly in order to identify the customer needs. For which several tools like questionnaire, discussion, brainstorming and historical data can be adopted. The main concern of the QFD approach is how to construct the house of quality (HoQ) including how to identify the correlation between the voice of customers or customer needs (commonly called Whats) and the engineering characteristics (commonly called Hows). The development of HoQ would involve cross-functional team or members from many different departments in industry. (Karsak, 2004a) highlighted that transferring value is the main purpose of the QFD that would be done by focusing on prioritized customer needs, translating them into design requirements and then communicating them throughout the organization in a way to ensure that details can be quantified and controlled. The structure of HOQ would consist of six rooms and would transform the customer needs into product characteristics that would be further deployed to develop process and production plans (Chan & Wu, 2002). A detailed of HOQ structure can be described as follows:

A detailed of House of Quality can be seen in **Figure 1**.

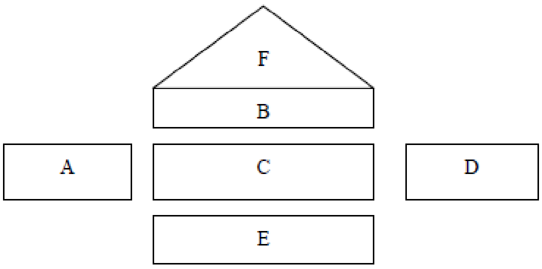

Figure 1. House of quality
A is customer requirements (Whats)
B is engineering characteristic (Hows)
C is the relationship between Whats and Hows
D is planning matrix
E is prioritizing characteristic engineering and target value
F is interrelationship between each engineering characteristic

Fuzzy QFD

When building QFD, all kinds of information that each and every step contains are often hidden with the message of subjective consciousness and inaccuracy. For instance, customer needs and evaluations. Throughout the years, many scholars applied Fuzzy Logic to convey the information. Such as, (Masud and Dean, 1993) first applied Fuzzy Logic to QFD, and added the customers' data as Triangular Fuzzy Numbers (TFN) during QFD to avoid the bias of subjective judgment, as well as better approach customers' requirements and satisfaction. (Khoo & Ho, 1996) integrated Fuzzy 1 Logic into the QFD structure and expressed the strength of relations with a symmetrical TFN. By calculating the relative importance of fuzzy numbers, they prioritized significance of both customers' and design requirements. (Chan, Kao, & Wu, 1999) modified a five-point scale of importance into fuzzy numbers, and adopted the Fuzzy Weight Average to several customers' responses to obtain their intuitive importance. Furthermore, they applied the Entropy Function to calculate the priority of CRs, and combined customers' intuitive importance and the priority of CRs into the importance priority of the overall CRs. (Vanegas & Labib, 2001) used the Fuzzy Membership Function to represent the degree of customers' satisfaction, and used fuzzy number calculation to combine the customers' and designers' requirements into weighted importance. To determine the level of a single customer's requirement satisfaction, they considered cost, technical difficulties, and limit of each design requirement, then multiplied the relevant design satisfaction of the same customer's requirement. Based on the satisfaction levels, they prioritized the CRs. (Chen & Weng, 2003) adjusted the relations in QFD with fuzzification of fixed Wasserman's normalization in order to determine the key coefficients of CR importance to establish the models, and Fuzzy Linear Programming to determine the optimized engineering design requirement combinations. (Kuo, Wu, & Shieh, 2009) proposed a fuzzy group method, which is applied to Eco-QFD for product development planning in order to reduce the vagueness and uncertainty in a group decision-making process. This fuzzy multi-objective model not only considers overall customer satisfaction, but also encourages enterprises to produce environmentally friendly products.

METHODOLOGY

Integration QFD & Fuzzy Theory for Cassava Chips

This paper proposes the integration of Fuzzy Theory into QFD method for on the design of Cassava Chips products. The QFD method with the Fuzzy Theory consideration would help the team of product design at the company identify the priorities of indicators that have to be targeted as the improvement effort for creating Cassava Chips product. The algorithm of the QFD with environmental concern can be described as follows:

Identify Customer Requirements (CRs)

The first step on the QFD method is how to identify voice of customer that would be called Whats on the HOQ.

Table 1. Identification Cassava Chips Requirements

Variable	Needs Atribute
Appearance	Opak Cassava Chips's appearance is good. Opak Cassava Chips well cooked. Opak Cassava Chips's tidy arranged in its package
Shape	Thickness of the Chips relatively same. Size of Opak Cassava Chips's pieces has a same size Variation Shape of the chips. (Not just round)
Color	Atractive Color. Opak Cassava Chips's color define the flavor. Opak Cassava Chips's color looks naturally.
Flavor	(Opak) Cassava Chips Spicy Flavor (Opak) Cassava Chips Tasteful Flavor (Opak) Cassava Chips Sweet Flavor (Opak) Cassava Chips Sweet &Spicy Flavor
Texture	Cryspy Taste of (Opak) Cassava Chips when consumed. Cryspy Taste of (Opak) Cassava Chips for all of it. Dried Texture of Chips Soft Texture of Chips
Portion	Chips's portion according to the packaging size Chips's portion according to the needs

	TA_1	TA_1	TA_1	….	TA_m
CR_1	r_{11}	r_{12}	r_{13}	….	r_{1n}
CR_2	r_{21}	r_{22}	r_{23}	….	r_{2n}
CR_3	r_{31}	r_{32}	r_{33}	….	r_{3n}
…	…	…	…	….	…
CR_n	r_{n1}	r_{n2}	r_{n3}	….	r_{nm}

Figure 2. Relation matrix Customer Requireents and Technical attributes

Identify Technical Attributes (TAs)

The second step of the QFD approach is how to identify the technical attributes or technical characteristics, so called as Hows. The identification of technical attributes (Hows) is how to answer the customer requirements (Whats). The process to identify technical attributes is wide, complex and uncertain. A systematic approach is needed to help the product development team identify technical attributes or technical characteristics.

Based on identification technical attributes, there are nine technical characteristics such as material quality, consistency of chips size, production process machine, temperature, steam duration, chips product control, Packaging Dimension, durability of chips.

Presentation of QFD with Fuzzy Logic

After customer requirements and technical attributes have been clearly identified, the next step is how to allocate weight to customer requirements (Whats) and also how to identify the relationship matrix between Whats and Technical attributes (Hows). This process would involve participation of some experts marketing, design and Processing Cassava Chips. The main concern of QFD with Fuzzy Theory is how to construct the house of quality (HoQ) including weight allocation to customer requirements and identify the relationship matrix between customer requirements and technical attributes provided. The illustrative relationship matrix is illustrated in **Figure 2**. Where CR is customer requirements and TA is technical attributes.

Commonly, the data for QFD method involves people assessment. The using of people's assessment would become subjective, vague and imprecise. The fuzzy logic approach that was developed to deal with the description activities, observations and judgments that are subjective, vague and imprecise would be employed to construct the HOQ including the identification of weight each customer requirements and also the relationship matrix between whats and hows in the QFD method. Several experts from Cassava Crips would be selected and they would give the assessment. The flow of fuzzy QFD can be described as follow:

Step 1: Identification linguistic term & Fuzzification

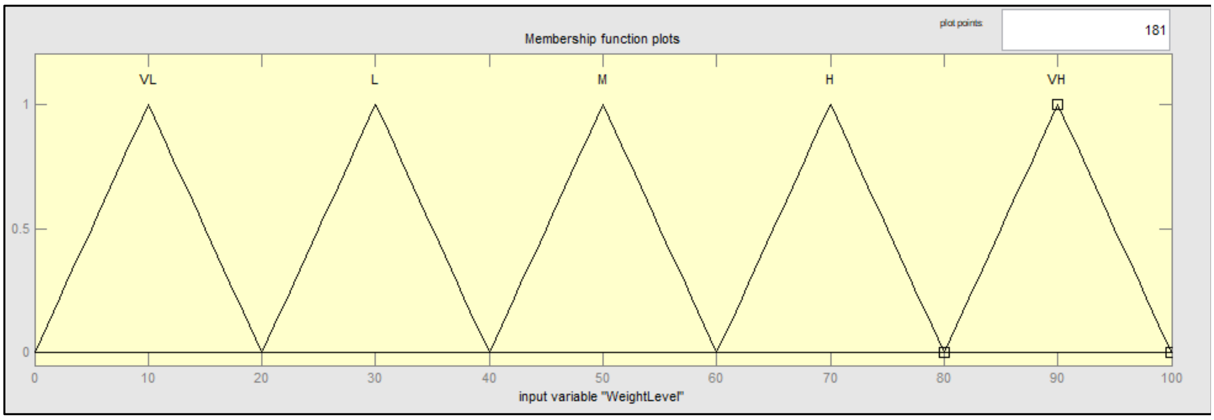

Figure 3. Weight Level Cassava Chips

The linguistic term is employed in this research and then transformed into triangular fuzzy number (TFN) to represent the assessment. To express the assessment the usage of linguistic term is more comfortable than numerical numbers. Several linguistic terms are used to express people's assessment. This study referred to the method proposed by Chen et al. (1992), and designed five-semantic-word sets: very unimportant (VU), unimportant (U), moderate (M), important (I), and very important (VI) in order to collect the interviewees' responses to each question. The membership function of these semantic values can be expressed by Triangular Fuzzy Numbers (TFN), and can be calculated for interviewees' semantic ranking. The results can serve as the measurement of importance for all questions. As interviewees have different opinions and interpretation to sentences, their defined ranges will differ. Therefore, this study used the average mean to conclude their fuzzy judgment. The equation is as follows:

$$E_{ij}^{k} = \left(\frac{1}{m}\right) \odot (E_{ij}^{1} \oplus + E_{ij}^{2} \oplus \dots \oplus E_{ij}^{k}) \quad (1)$$

where, E_{ij}^{k} is the average of all m interviewees' responses to Project i reaching standard level j, which can be expressed as a TFN:

$$E_{ij} = (LE_i, ME_{ij}, UE_{ij}) \quad (2)$$

The project proposed by Buckley (Buckley, 1985) was used to determine the terminal values.

$$LE_{ij} = (\sum_{k=1}^{m} LE_{ij}^{k})/m \quad (3)$$

$$ME_{ij} = (\sum_{k=1}^{m} ME_{ij}^{k})/m \quad (4)$$

$$UE_{ij} = (\sum_{k=1}^{m} UE_{ij}^{k})/m \quad (5)$$

Step 2: Defuzzification

Defuzzification is the process of turning fuzzy numbers into precise values. There are several common conversion methods, such as Center of Gravity Defuzzification, Center of Sum Defuzzification, Center of Largest Area Defuzzification, First of Maxima Defuzzification, Last of Maxima Defuzzification, Middle of Maxima Defuzzification, and Height Defuzzification. This study adopted Center of Gravity Defuzzification. According to Tseng and Klein's (1989) assumption that the membership function of fuzzy set $\tilde{A}$ is $U_{\tilde{A}}(X_i)$ and when fuzzy number is TFN, $\tilde{A} = (L_i, M_i, U_i)$ The equation is:

$$F_i = \frac{\lfloor (U_i - L_i) + (M_i - L_i \rfloor}{3} + L_i \quad (6)$$

where F_i is the Fuzzy weights. Finally, the fuzzy weights were normalized

$$W_i = F_i / \sum_{i=1}^{m} F_i \quad (7)$$

Table 2. TFN Calculation

CRs		TFN			F	W (%)	RANK
DIMENSI	**ITEM**	**L**	**M**	**U**			
Appearance (15.92%)	Opak Cassava Chips's appearance is good.	70	75	82	75.67	5.67	2
	Opak Cassava Chips well cooked.	55	67	70	64.00	4.80	17
	Opak Cassava Chips's tidy arranged in its package	60	73	85	72.67	5.45	7
Shape (16.32%)	Thickness of the Chips relatively same.	62	75	80	72.33	5.42	8
	Size of Opak Cassava Chips's pieces has a same size	62	74	83	73.00	5.47	16
	Variation Shape of the chips. (Not just round)	60	73	84	72.33	5.42	5
Color (15.87%)	Atractive Color.	62	73	82	72.33	5.42	9
	Opak Cassava Chips's color define the flavor.	58	68	71	65.67	4.92	6
	Opak Cassava Chips's color looks naturally.	63	74	84	73.67	5.52	10
Flavor (20.92%)	(Opak) Cassava Chips Spicy Flavor	55	67	80	67.33	5.05	13
	(Opak) Cassava Chips Tasteful Flavor	60	68	82	70.00	5.25	12
	(Opak) Cassava Chips Sweet Flavor	50	68	82	66.67	5.00	15
	(Opak) Cassava Chips Sweet &Spicy Flavor	70	75	80	75.00	5.62	4
Texture (20.77%)	Cryspy Taste of (Opak) Cassava Chips when consumed.	67	81	83	77.00	5.77	1
	Cryspy Taste of (Opak) Cassava Chips for all of it.	60	70	85	71.67	5.37	11
	Dried Texture of Chips	50	68	82	66.67	5.00	14
	Soft Texture of Chips	48	67	70	61.67	4.62	18
Portion (10.20%)	Chips's portion according to the packaging size	70	75	81	75.33	5.65	3
	Chips's portion according to the needs	48	65	69	60.67	4.55	19

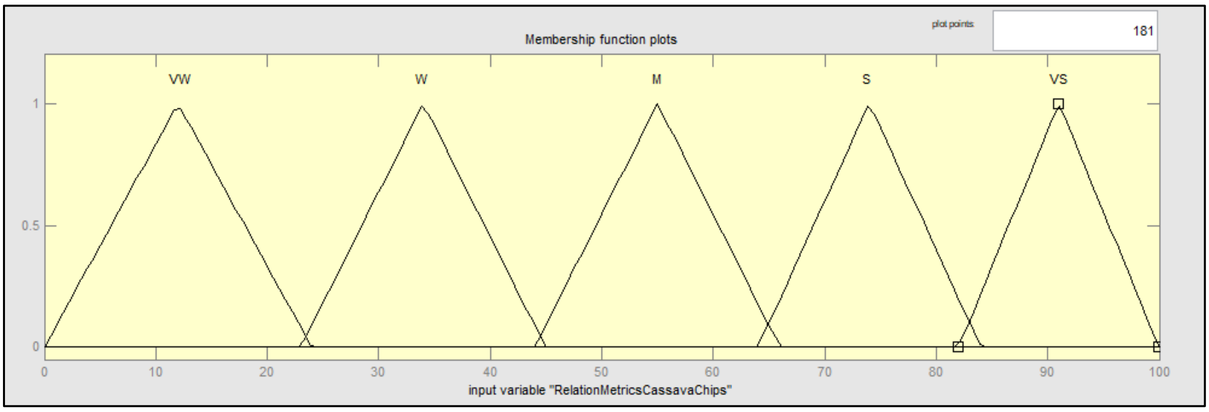

Figure 4. Relation Matrics Cassava Chips

Weight Level (X)

This study divided the semantic weights of CRs into five levels, which are 'Very Low (VL)', 'Low (L)', 'Medium (M)', 'High (H)', and 'Very High (VH)'. With the responses to the five intervals of (0, 100) from some respondents, this study further defined their correspondent Fuzzy Weights, which can be converted into TFN When establishing principle weights of CRs, in order to show the importance of CRs's, some experts were invited to evaluate the principles of the semantic weights of CRs. After confirming the semantic weights, they were converted into fuzzy weights through the conversion method of **Table 2**. Then through TFN calculation.

Relation Matrices

The inner matrices of HoQ are called Relation Matrices. By the corresponding principle items of CRs and the items of TAs features, systematic analyses were conducted to establish relation matrices between them, thus identifying their interrelation. This study divided TAs feature items as five levels: 'Very Week (VW)', 'Week (W)', 'Medium (M)', 'Strong (S)', and 'Very Strong (VS)'. With the expert responses to the five intervals of (0,100), the fuzzy weights were determined, and converted into TFN. When establishing the Relation Matrics, five experts rated the semantic evaluations.

Table 3. Relation Matrices VOC and TAs using Fuzzy Logic

VOC \ TAs			Material quality			Consistency of Chips Size	production process machine				Temperature	steaming duration			Chips Product Control		Packaging Dimension		Durability of chips	
DIMENSI	ITEM	W (%)	Type of Cassava	Spices	Flavor ingredients quality	Type of Press machine (Traditional / Manual Machine)	Grinding Machine	Rolling Machine	Press Machine	Vacuum Fraying machine	Stove	30 minutes	45 minutes	1 hour	Labor quality	sorting tool quality	Tube	plastic sealer	Storage	room temperature
Appearance	Opak Cassava Chips's appearance is good.	5.67	57			91	91	86	91	86	65			86	57					
	Opak Cassava Chips well cooked	4.80	49			83		91	86	91	91									
	Opak Cassava Chips's tidy arranged in its package	5.45				91			91											
Shape	Thickness of the Chips relatively same.	5.42	57				91	91						91						
	Size of Opak Cassava Chips's pieces has a same size	5.47				91			91											
	Variation Shape of the chips. (Not just round)	5.42							100											
Color	Atractive Color.	5.42	86	91	91									83						
	Opak Cassava Chips's color define the flavor.	4.92		91	91															
	Opak Cassava Chips's color looks naturally.	5.52	91	91	91					91	86									
Flavor	(Opak) Cassava Chips Spicy Flavor	5.05		91	91														86	57
	(Opak) Cassava Chips Tasteful Flavor	5.25	86	86	86															
	(Opak) Cassava Chips Sweet Flavor	5.00	86	86	86															
	Opak) Cassava Chips Sweet & Spicy Flavor	5.62	86																	
Texture	Cryspy Taste of (Opak) Cassava Chips when consumed.	5.77	57				91		65	91	86			86					86	68
	Cryspy Taste of (Opak) Cassava Chips for all of it.	5.37					86	86	65	91	86									
	Dried Texture of Chips	5.00	68			86	86		86	91	86									
	Soft Texture of Chips	4.62	68			86	86	91	86					86						
Portion	Chips's portion according to the packaging size	5.65				86	91		91								86	86		
	Chips's portion according to the needs	4.55															86	86		
I_j^{vos}	Absolute		41.9	23.3	23.3	27.4	28.2	23.0	40.2	29.0	26.7	0.0	0.0	23.3	3.2	0.0	0.0	0.0	5.0	3.9
	Opposite (%)		14.0	7.8	7.8	9.2	9.5	7.7	13.5	9.7	9.0	0.0	0.0	7.8	1.1	0.0	0.0	0.0	1.7	1.3
	Rank		1	7	8	5	4	10	2	3	6	17	18	9	13	14	15	16	11	12

Synthetic Fuzzy Evaluations

The normalized fuzzy weights and normalized fuzzy evaluation relation matrices were multiplied, then summed up to obtain the synthetic fuzzy evaluations, as shown in Equation 8.

$$I_j^{voe} = \sum W_i^{voe} \, x \, R_j^i \quad (8)$$

where, R_j^i is the original score in the matrix, and I_j^{voe} is synthetic fuzzy

RESULT

From five experts, the corresponding fuzzy weights were defined, which can be converted into TFN. They are Very Week (0, 12, 24); Week (23, 34, 45); Medium (44, 55, 66); Strong (64, 74, 84); Very Strong (82, 91, 100).

CONCLUSION

From result of VoC seen that customer wants Cassava Chips with product Flavor value equal to 20,92%, product Texture value (20,77%) and shape value (16,32%). Flavor, texture and shape determine the quality of Cassava Chips products.

Based on Matrix Value Relation between VoC & TAs with Fuzzy-QFD method, the matrix value for production machine design is press machine (13,5%), Vacuum Fraying machine (9,3%), and Grinding machine (9,5%). To get quality cassava chips product with standard form, savory taste and crunchy texture when consumed determined also by type of cassava, from matrix relation VoC and TAs result value type of cassava equal to (14,0%). Types of cassava and production process mechanization greatly affect the quality of cassava opak chips

Fuzzy Logic was used to reduce the subjectivity of VoC, and an R&D model of Cassva Chips product design was developed, known as Fuzzy QFD. The proposed model can be used as a R&D tool that considers quality, cost, and *Customer Requirements*. Fuzzy Logic was used to effectively reduce the ambiguity of VoC. With HoQ planning, the key TAs of product design were obtained, thus helping enterprises to allocate their limited resources to the key dimensions.

Disclosure statement

No potential conflict of interest was reported by the authors.

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