Proceeding of International Conference on Multidisciplinary Research for Sustainable Innovation, Vol. 1 No. 1 (2024)
DOI to be assigned soon

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Research Paper

Production System by Considering Hazard Analysis and Critical Control Points

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Received : January 29, 2024	Revised : February 5, 2024	Accepted : March 9, 2024	Online : March 14, 2024

Abstract

Black Garlic granules serve to help prevent and treat diabetes and cardiovascular disease. In this study, a BG-based liquid supplement production system was designed which is expected to become a BG-based liquid supplement production standard that pays attention to product safety, product quality and production efficiency. This research will design BG's production process to meet quality specifications and food safety standards along with the production system. The research will be conducted by conducting Taguchi experiments and then continued with Hazard Analysis and Critical Control Points (HACCP). At the experimental stage, several important BG quality attributes were selected in response. The factors that affect quality are determined through Focus Group Discussions involving company stakeholders. Experiments were conducted using laboratory scales. The results of Taguchi's experiments that have been carried out, it is concluded that using the optimal level settings chosen can reduce SAC levels, namely A1 = Cleaning and Weighing Equipment (Using a Washing Bucket), B1 = BG Formulation Temperature (30°C), C1 = BG Formulation Time (60 minutes), D2 = Cooling Process (Accelerated), E1 = Storage Packaging (Aluminum Sachet), F1 = Storage Temperature (28°C), G1 = BG Treatment (Peel).

Keywords: *Liquid black garlic*, *Robust Design*, *HACCP*, *Experiment*

INTRODUCTION

Black garlic commonly known as "black garlic" is garlic that has gone through a heating and fermentation process under controlled conditions for several weeks (Kim et al., 2013). This process turns the garlic black and changes its chemical composition. Black garlic contains various compounds that can provide various health benefits. Some of the benefits associated with consuming black garlic include: improving heart function, liver function, and kidney function in patients with coronary heart disease (Liu et al., 2018), reducing SGOT and SGPT (Kawasaki et al., 2017), lowering cholesterol and triglycerides (Jung et al., 2014), improve sleep quality, facilitate defecation, improve stiff body complaints (Ichimaru et al., 2014), and is still the subject of further research today.

Taguchi Design, also known as the Taguchi Method, is an experimental design approach developed by Dr. Genichi Taguchi, a Japanese engineer and statistician. The Taguchi method aims to improve product and process quality by identifying factors that influence quality and efficiently optimizing experimental conditions. From the process as described above, it is necessary to monitor raw materials and process stages so that food safety is achieved by implementing HACCP (Hazard Analysis and Critical Control Points) which functions to identify and control hazards associated with the production of liquid BG supplements. Improving product quality by using

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robust design in the production system, so that the production process runs consistently and stably (Susanto et al., 2022). By implementing HACCP, and robust design in the production system, a commitment to producing products that are safe, high quality, and consistent will be achieved. This will help increase consumer confidence and strengthen the product's image.

LITERATURE REVIEW

Hazard Analysis and Critical Control Points (HACCP)

Food safety guarantees continue to develop in line with ever-increasing consumer requirements and in line with the quality of human life. Quality assurance and food safety continue to develop in accordance with consumer requirements. This has had the impact of changes starting from the food business without supervision, then monitoring the final product, to monitoring the production process for total quality assurance. Food quality, especially food safety, cannot only be guaranteed by the results of final product tests from the laboratory. Safe products can only be obtained from good raw materials and handled well to produce a good final product. To control the monitoring system and to guarantee "food safety" there are two options, namely conventional and the HACCP system (Winarno, 2012). The conventional meaning is to use Good Manufacturing Practices (GMP) and testing. Traditional weaknesses are that microbiological hazards are not represented by Statistical Quality Control (SQC), it takes a long time, costs are expensive and testing does not find or control the cause.

Robust Design

Robust Design is a system or product design method that aims to create a product or system that can function optimally even in unexpected or undesirable situations and is able to survive and maintain its performance even if it experiences disturbances or errors in its parts. In Robust design, the product or system is designed in such a way that it can overcome the variability that occurs in different environmental or operational conditions and is able to adapt to unexpected changes in conditions. This is done by identifying various possible disruptions or errors that may occur during the operation of the product or system and designing solutions to overcome or avoid these problems. From this robust process, product purity will be obtained and it will be economically more efficient. To predict and control robustness, a clear understanding of the interactions between input and output variables is required. Real-life sources of variation can include inconsistencies in material properties, such as batch-to-batch variations, systematic errors in process conditions, random, time-varying process/cellular noise, and inaccurate process designs.

Process intensification and increasing process robustness require an understanding of the underlying methods and interactions through the incorporation of innovative measurement, control, and modeling approaches. A clear understanding of all process operations that affect quality in the manufacturing process (design space) and associated controls is the basis for a robust production process. Robustness affects the entire process chain, from upstream to downstream processing and product formulation. (Roy, 2010).

RESEARCH METHOD

Planning Stages

Data collection

Data collection is an activity carried out to gather the necessary data for research, whether through direct observation, interviews, or existing data available at the research site. The data utilized consists of observations during the production process of the single Black Garlic supplement.

Table 1. Specifications Data for Liquid Black Garlic Supplement Product

Specifications	Description
Product Name	BG Liquid
Raw Materials	Single Black Garlic, red ginger extract, peppermint, stevia, xanthan gum, and sodium benzoate.
Packaging Type	Aluminum-Printed Plastic with a width of 12 cm.
Storage Conditions	Store in a dry place, protected from direct sunlight.
Expiration Date	± 2 years
Label	Product name, manufacturer name, Product logo, product type, composition, nutritional information, storage instructions, expiration date, production code, net weight, product description
Consumer	All ages (from children to adults), with a preference for adult consumers.
Distribution	Distribution is carried out using the FIFO (First In, First Out) method. Direct contact with consumers (direct transactions) is established. Additionally, reseller services are utilized, which involve delivery by box trucks and storage in cardboard boxes.
Product Usage	2 times a day, 1 sachet each time; Children's dosage is half.
Processing	Extraction process
Product Characteristics	Thick liquid, sweet, menthol, in a 15 ml size.

Variable Identification

In this study, there are three types of variables: constant variables, dependent variables, and independent variables. Constant variables are those whose values can be varied but are set. Independent variables are variables whose values are varied to observe their effects on dependent variables. Dependent variables are variables that depend on independent variables.

a. Independent variables in this research include the following:
   - The ratio of raw materials of Black Garlic to the solvent (water) during the black garlic extraction process. This variation aims to determine its effect on the S-Allyl-Cysteine content.
   - Black garlic extraction temperature. This variation aims to determine its effect on the S-Allyl-Cysteine content.
b. The dependent variable in this study is the production time at each station.
c. In the context of this research, constant variables used are as follows: The raw material used is black garlic.

Design Stage

In the design stage, analysis is conducted using Good Manufacturing Practices (GMP), followed by the identification and monitoring of Sanitation Standard Operational Procedure (SSOP) with Critical Control Points (CCP) for the Liquid Black Garlic Supplement product. Once a new design is obtained, design optimization is carried out through scenario-based methods.

Analisis Good Manufacturing Practices (GMP)

The analysis of GMP conditions is conducted by comparing the compliance with applied GMP requirements with the GMP standards for Good Manufacturing Practice based on the Safety, Quality, and Nutrition of Processed Food Guidelines, Government Regulation of the Republic of Indonesia Number 28 of 2004, Article 41. Evaluation is performed by observing the company's GMP conditions through observation and interviews.

Identification and monitoring of Sanitation Standard Operational Procedure (SSOP) with Critical Control Points (CCP).

After implementing Good Manufacturing Practices (GMP), the next step is the analysis of Sanitation Standard Operational Procedure (SSOP). SSOP must be established and adhered to by the company before implementing HACCP. Several aspects that need to be evaluated include water safety, cleanliness of surfaces in contact with food, prevention of cross-contamination, sanitation facilities, protection from adulteration, labeling and proper storage, employee health control, and pest prevention.

Scenarios and Design Optimization

After obtaining the results of identification and monitoring, researchers conduct HACCP analysis, including product description, identification of usage plans, flowchart development, on-site flowchart confirmation, hazard identification, determination of Critical Control Points (CCP), and establishment of critical limits for each CCP (Critical Control Point).

Table 2. Critical Control Points (CCP) for Liquid Black Garlic Supplement Product

CCP	Danger	Critical Limits
Garlic cleaning (with water).	Physical: Dust, gravel, soil, insects, dirt, other foreign bodies.	No physical contamination found.
Prose Dating I	Biologi: Staphylococcus aureus, Escherichia coli, Kapang (Fusarium sp, Aspergillus niger)	Meet microbial contamination test standards in food.
Sun-drying	Physical: Dust, insects, motor vehicle fumes	No physical contamination found
		Sun-drying time is carried out ≤ 1 day
Fermentation	Biology: Airborne unwanted microorganisms, Clostridium botulinum, Clostridium perfringens	Meet microbial contamination test standards in food.
		The temperature used for fermentation ≥ 60^{o}C

Simulation Design Stage (Robust Design)

This method's analysis is used as an initial interpretative approach in the research. The method is effective, especially when the experimental response is associated with the NB (Nominal-Bigger) situation, but it is most effective in handling LB (Low-Bigger) or HB (High-Bigger) characteristics. The observational method is a simple and straightforward way to interpret experiments with an orthogonal matrix structure. This approach focuses on experiments with similar outcomes and technical significance. Typically, a portion of experiments with similar outcomes will form 1/2 of the experiments (one strong factor), 1/4 of the experiments (two strong factors), 1/8 of the experiments (three strong factors), and so on when using a two-level Orthogonal Array (OA). These outcomes will be divided into groups of 1/3 of the experiments (one strong factor), 1/9 of the experiments (two strong factors), and so on when using a three-level OA. Once groups with consistent and desired outcomes are identified, the most important factor levels can be recognized for that group. By only observing experimental data, finding groups of experiments with desired outcomes, and identifying columns (factors and interactions) with the same levels for that group, the research can obtain information about important factors and their interactions.

FINDINGS AND DISCUSSION

Determination of Influential Factors

Based on the identification of factors considered influential as contained in Table 4, the following is a grouping of control factors and noise factors along with signal factors and scales in

the study shown in Table 3.

Table 3. Control factors and noise factors in research

Types of Factors	Factor
Control	Cleaning and Weighing Tools
	BG Formulation Temperature
	BG Formulation Time
	Cooling Process
	Storage Packaging
	BG Pasteurization Temperature
	Storage Temperature
	Behaviour on BG
Noise	Transportation Time
	BG Environmental Cleanliness
	Material Condition
Signal	SAC rate on BG
Skala	Temperature and Formulation Time
	Temperature and Storage Time

Based on the determination of control factors and noise as contained in Table 4, it was decided that 7 control factors would be used in the study. The following is an explanation of the determination of the control factor selected in the study and noise factor.

1. Cleaning and weighing tools were chosen because they were the first objects to come into direct contact with BG and other supporting materials. Therefore, this factor can affect the SAC levels of BG raw materials which will also affect SAC levels.
2. The temperature and time of the BG formulation were chosen based on research conducted by (Saputra, 2023) which showed that temperature and time had an effect on the SAC levels of BG products.
3. The cooling process was chosen because there is an effect of a rapid decrease in temperature on SAC levels. The cooling process is the process of lowering the BG temperature after going through the formulation process.
4. Storage packaging was chosen because the packaging is the main protector of liquid BG from external contaminants. The tighter a package, the better it will be for BG products.
5. The temperature and storage time were chosen because it is an important process to preserve BG products after packaging. Good storage can reduce or inhibit the growth of microorganisms.
6. Transport time is included in the noise factor because it cannot be controlled precisely. In this study, transportation time was tried as quickly as possible so that there were no gaps for bacterial contamination as much as possible.
7. The cleanliness of the BG environment and the condition of the supporting materials are included in the noise factor because researchers cannot control the cleanliness of BG products and other supporting materials. In addition, researchers also focus more on the production process of liquid BG production.

The determination of levels in each factor is obtained from the results of literature studies and discussions with the laboratory. Table 4 below is the determination of the level of factors used in the study.

Table 4. Determination of Factor Levels Used in Research

No.	Factor	Level Factor	
		1	2
1	Cleaning and Weighing Tools	Using a Washing Bucket	Using Hands
2	BG Formulation Temperature	30°C	70°C
3	BG Formulation Time	60 minutes	80 minutes
4	Cooling Process	At room temperature	With Acceleration
5	Storage Packaging	Aluminium Sachet	Sterilization Plastic Bottles
6	Storage Temperature	28°C	30°C
7	Behaviour on BG	Coupe	Not Peeled

Table 5. Degree of Freedom Calculation

No.	Factor	DF
A	Cleaning and Weighing Tools	(2-1)
B	BG Formulation Temperature	(2-1)
C	BG Formulation Time	(2-1)
D	Cooling Process	(2-1)
E	Storage Packaging	(2-1)
F	Storage Temperature	(2-1)
G	Behaviour on BG	(2-1)
Total		7

Table 6. Results of Taguchi Experimental Data Measuring SAC Levels

Eksperiment	Faktor Level							Replication			Average
	A	B	C	D	E	F	G	R1	R2	R3	
1	1	1	1	1	1	1	1	153	222	175	183
2	1	1	1	2	2	2	2	201	166	214	194
3	1	2	2	1	1	2	2	211	219	227	219
4	1	2	2	2	2	1	1	214	223	130	189
5	2	1	2	1	2	1	2	253	186	234	224
6	2	1	2	2	1	2	1	224	192	230	215
7	2	2	1	1	2	2	1	218	235	241	231
8	2	2	1	2	1	1	2	172	182	223	192

Table 7. analysis of variance mean values

Source	Sum of Squares (SS)	df (v)	Mean Square (V)	F ratio	Percent of Contribution	F tabel
A	2301,041667	1	2301,041667	26,16	6,705714707	4,493998478
B	84,375	1	84,375	0,96	0	4,493998478
C	828,375	1	828,375	9,42	0	4,493998478
D	1717,041667	1	1717,041667	19,52	3,950862365	4,493998478
E	301,0416667	1	301,0416667	3,42	0	4,493998478
F	1855,041667	1	1855,041667	21,09	4,601837748	4,493998478
G	40,04166667	1	40,04166667	0,46	0	4,493998478
Error	14072	16	879,5	90,8965795	95,42214142	
Total	21198,95833	23		100	100	

μ conffirmation – Cl mean ≤ μ conffirmation ≤ μ conffirmation + Cl mean

217,8 – 127,086 ≤ μ conffirmation ≤ 217,8 + 127,086

90,713 ≤ μ conffirmation ≤ 344,886

A confidence interval is obtained for the optimal process mean value with a confidence interval for the optimal process average.

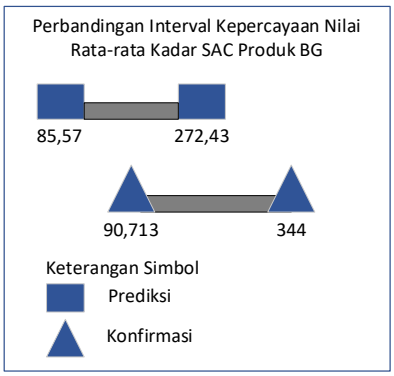

Figure 1. Comparison of the confidence interval of a confirmation experiment with the Taguchi experiment.

CONCLUSIONS

From the results of comparing the confidence interval with Taguchi's experiment, it can be seen that the confirmation experiment can be accepted with consideration of the confidence interval. Based on the confidence interval of the mean value and SNR, it can be concluded that the decision is accepted, meaning that the results of Taguchi's experiment can be used and the optimal level setting can be used as a reference in reducing SAC levels.

Based on Taguchi's experiments, it was concluded that the use of the selected optimal level setting to reduce SAC levels was A1 = Cleaning and Weighing Equipment (Using a Washing Bucket), B1 = BG Formulation Temperature (30oC), C1 = BG Formulation Time (60 minutes), D2 = Cooling Process (With Acceleration), E1 = Storage Packaging (Aluminum Sachet), F1 = Storage Temperature (28^{o}C), G1= Treatment on BG (Peel).

The optimal level setting obtained is used to run confirmatory experiments. Confirmatory experiments were carried out as many as 10 replications. This calculation is useful to prove whether a confirmatory experiment using the selected optimal level setting is acceptable or not. The results of a comparison of the confidence interval between Taguchi's experiment and confirmation are shown in the following table.

The conclusions that can be drawn based on research conducted on black garlic extraction products are as follows Based on Taguchi's experiments that have been conducted, it was concluded that the use of the selected optimal level setting can reduce SAC levels is A1 = Cleaning and Weighing Tool (Using Washing Bucket), B1= BG Formulation Temperature (30oC), C1 = BG Formulation Time (60 minutes), D2 = Cooling Process (With Acceleration), E1 = Storage Packaging (Aluminum Sachet), F1 = Storage Temperature (28oC), G1 = Treatment on BG (Peel).

LIMITATION & FURTHER RESEARCH

The limitations of the study are those characteristics of design or methodology that impacted or influenced the interpretation of the findings from your research. Further research should suggest the number of gaps in our knowledge that follow from our findings or to extend and further test of the research.

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