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Optimization of Brushing, Bubble, and Microbubble Techniques Using Taguchi Method for Raw Edible Bird Nest Cleaning Purpose

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ABSTRACT

The paper presents the parameter setting and optimizing the brushing, bubble, and microbubble techniques to clean the raw edible bird nest (EBN). EBN is nourishment created entirely from the secretions of swiftlets, with no added ingredients. Because of its medical benefits, cleaned EBN is in high demand. In general, the raw EBN has been cleaned using human manual cleaning with the help of tweezers. However, this method is lengthy as it took about one hour to clean 1 EBN fully. Hence, some mechanical cleaning techniques are needed to clean the raw EBN to improve the cleaning time and cleanliness. This paper aims to optimize the three mechanical cleaning techniques: brushing, bubble, and microbubble. Taguchi Method is used to design and optimize the combination setting of all parameters. The chosen optimized parameter set will then be tested to find the optimal parameter sets for the cleaning process. The time setting for each parameter is set at 30, 45, and 60 seconds. Each of these parameters is tested to obtain the best-optimized parameter. Once the best-fit parameters are identified, the experiment is conducted using the three selected parameters with three different sequences to find the most effective and efficient sequence to clean the raw EBN. With the experiment being carried out, the output of the best sequence of the cleaning process is Sequence 1, which contributes to the cleanliness of 66.18% and cleaning time of 7 minutes.

Keywords: Brushing, bubble, edible birds nest, microbubble, optimization, Taguchi method

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INTRODUCTION

Edible bird nest is produced by swiftlets from their saliva (Deng et al., 2006). Its demand increased day by day due to its benefits to human health. EBN can be processed in a few different products, such as skin care products, tonic foods, and medical products (Haghani et al., 2016). Hence many entrepreneurs have been involved in harvesting and selling this EBN. However, before selling it, the EBN must be cleaned. Impurities are the main things to be cleaned during the cleaning process (Thida & Danworaphong, 2017). The cleaning process is complicated due to impurities such as feathers, dirt, and tiny sands being stuck together inside the EBN (Thorburn, 2015). Conventional cleaning method has been applied to clean the raw EBN (Chua & Zukefli, 2016). The conventional method includes four processes: soaking of raw EBN, cleaning the raw EBN, reshaping of cleaned EBN, and drying the EBN (Gan et al., 2016). The conventional cleaning method is one of the oldest cleaning methods in the EBN industry. However, this conventional method took about one hour to clean 1 EBN fully (Ibrahim et al., 2009). In order to increase productivity, much workforce is required to clean the EBN. Hence to avoid this issue, some mechanical cleaning techniques have been introduced to clean the raw EBN. The current mechanical cleaning techniques use bubble, microbubble, and brushing techniques as the cleaning techniques. However, the performance of the current techniques during the cleaning process still has not been able to cover the entire bird nest, particularly the hard impurities. As a result, the maintenance time and cleanliness still be increased before being sold to consumers. Hence, this project mainly focuses on optimizing the mechanical cleaning techniques to get better cleanliness and a shorter cleaning time of raw EBN. Therefore, testing on the application of mechanical cleaning techniques has been carried out to obtain a better result on cleaning time and cleanliness.

LITERATURE REVIEW

This mechanical cleaning technique for raw EBN is specifically for small and medium-sized businesses, as the cleaning mechanisms available on the market are meant for large production enterprises and are quite large (Nandi et al., 2014). Those cleaning mechanisms are costly, and many small business owners have had difficulty affording one (Moallem et al., 2017). Therefore, this mechanical technique will solve all their difficulties. They will be able to afford this gadget because it has a reasonable price on the market. This technique is also mobile, allowing it to be transported to any location at any time. The current three mechanical cleaning techniques being applied to clean the raw EBN are brushing, bubble, and microbubble. These mechanical techniques are introduced by combining them to clean the raw EBN. Microbubble and bubble techniques are cleaning processes by a bubble formed by which liquids and gases, combined under pressure, form bubbles of varying sizes (Matsuura et al., 2016). Microbubble technology is very effective in the cleaning process of micro-materials from EBN. This cleaning will intrude the liquid inside the sink and create rapid bubbles forming and collapsing. As the bubbles collapsed, the cleaning solution rushed hard to clean the area of the nest (Fuchs, 2002). The brushing technique is by a combination of brushing and robotic arm. The advanced technology system will result in an increase in the efficiency of the raw EBN cleaning technique.

To achieve the optimum version of these mechanical cleaning techniques, researchers had to look through journals and research papers to figure out how to clean raw EBN—also, examining the existing cleaning technique, which is the traditional cleaning method. In order to achieve the best outcomes, the parameters of the mechanical cleaning techniques have been studied. The recommended parameter sets are then optimized and validated through experimentation. The project's major goal is to improve cleanliness and reduce the cleaning time in terms of cleaning techniques. The brushing technique is built around an automobile robotic arm. This system employs an automotive robotic arm, a machine vision lens, lightning, and a platform-based construction to eliminate impurities from raw EBN (Subramaniama et al., 2015). Cleaning using bubble and microbubble techniques can remove contaminants down to the raw EBN's dead-end surface. Cleansing and processing a bird's nest with the newest nanobubble technology (Matsuura et al., 2016). Microbubbles with diameters of 0.2-10μm are produced by cavitation, shearing, and electrolysis (Matsuura et al., 2016). The technique was designed to produce microbubbles by directing air to a flat plate bored with pores through the compressor and adjusting the rate of rotation with the engine. Slice through the bubbles will use shear forces to reduce the diameter of the bubble by increasing the speed of rotation (Lin et al., 2015). Therefore, in a short period, microbubbles are produced (Kim et al., 2017). Microbubbles with a diameter of 0.2 microns will penetrate deep into the cracks of food to eliminate contaminants, allowing raw EBN to be easily washed (Agarwal et al., 2011).

One of the most important aspects to be considered when cleaning raw EBN is its nutrition. The cleaning process must not affect the nutritional level of an EBN. The chemical composition of EBN has an impact on the purification process quality. This procedure is crucial since it will aid EBN producers in developing strategies for cleaning chemical traces from the gathered nests. EBN is made up of approximately 50–60% protein, 25% carbohydrate, and 10% water, with minor amounts of nutrients such as calcium, phosphorus, potassium, and sulfur. The EBN has 17 distinct amounts of amino acids, according to a deep performance liquid chromatography analysis. These are aspartic acid, glutamic acid, creatine, glycine, histidine, threonine, arginine, alanine, isoleucine, leucine, lysine, and phenylalanine (Zukefli et al., 2017). The demand for these nutrients is the source of why EBN price is skyrocketing. As a result, the cleaning procedure must be environmentally friendly and have no negative impact on EBN nutrition, as the price of cleaned EBN is determined by its quality. Thus, it is important to design a suitable food processing technique analogous to chemical processes to meet process requirements such as material capacity, component strength, operation efficiency, and energy transfer during food processing. Appropriate food processing methods should be corrosion-resistant, cost-effective, and operate without posing any occupational dangers to the workers (Xian et al., 2017). Figure 1 shows the raw uncleansed EBN, while the cleaned EBN is shown in Figure 2.

Figure 1. Raw uncleansed EBN (Wong et al., 2018)

Figure 2. Cleaned EBN (Wong et al., 2018)

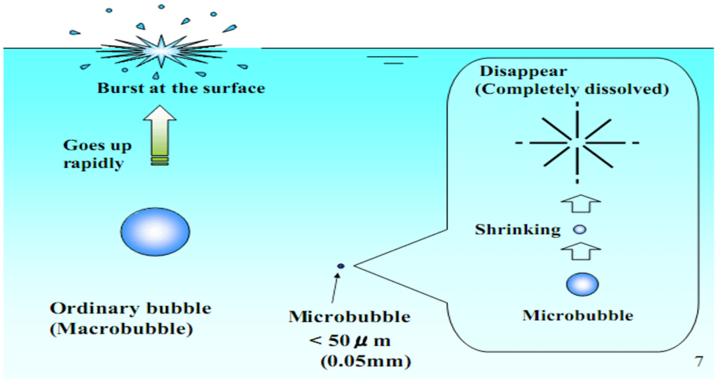

Figure 3. The difference between regular bubbles and microbubbles (Siswanto, 2019)

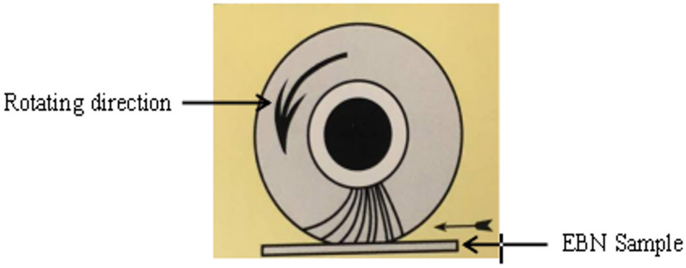

Figure 4. Brushing technique (Moallem et al., 2017)

Figure 3, the difference between bubble and microbubble has been described. The regular bubbles are at the range diameter of 1–2mm are generated at the bottom of the water surface by air diffusers, and they burst when they reach the water surface. The microbubble has a range diameter of 0.2 microns, generated under the surface of the water. Microbubbles are negatively charged where they attract positively charged particles such as untreated EBN impurities (Kovalenko et al., 2016). The negatively charged microbubbles attract dirt while moving up to the water surface. It shrinks from water pressure while traveling up to the surface carrying dirt. Then the microbubble collapses and leaves the dirt on the water surface. Figure 4 shows the brushing mechanism. The brush is attached at the end part of the arm to clean raw EBN.

METHODOLOGY

The stages for the methodology are optimizing the EBN mechanical cleaning techniques, setting up the optimized cleaning parameters, and validating the proposed parameters set through the experiments.

Experimental Set-Up for Bubble and Microbubble Cleaning Techniques

Figure 5 shows the set-up of the bubble and microbubble technique. Two types of bubble and microbubble diffusers are employed in this experiment. Different types of diffusers produce different sizes of bubbles according to the diffusers' bubble pore sizes, as explained in Figure 3. The chosen bubble size is 1–2mm, and for microbubble, the chosen bubble size is 0.5–100µm. The bubble and microbubble cleaning time range is chosen for a specific period. This experiment aims to calculate cleanliness by finding the difference in EBN weight before and after the experiment. This study will be able to calculate the removal rate of each specimen using this formula. In contrast, the removal rate calculation is presented in Equation 1.

$$\text{Removal Rate (g/min)} = \frac{(Wu - Wc)}{t}, \quad \textbf{(1)}$$

W_u = Weight of unclean EBN (g)

W_c = Weight of clean EBN (g)

t = microbubble releasing time (min)

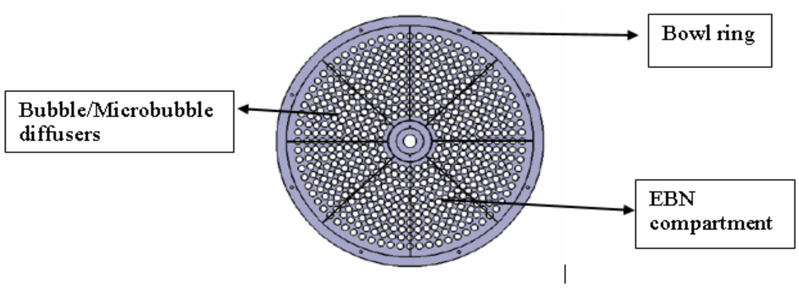

Figure 5. Bubble and microbubble cleaning technique set up

Standard of Procedure (SOP) of Bubble and Microbubble Cleaning Technique

Some procedures need to be identified and followed in experimenting correctly. Table 1 shows the procedure for experimenting.

Table 1

SOP of bubble and microbubble cleaning technique set up

No	Procedure
1	Prepare three specimens to be analyzed.
2	Place the specimens into the EBN compartment.
3	Make setting for the bubble of size 1–2 mm to run.
4	Collect the data received.
5	The experiment is repeated using a microbubble size of 0.5–100 µm.
6	The data is collected and computed into a table.

Experimental Setting of Brushing Technique

The brushing arm in Figure 6 regulates the movement of the brush-up and down to clean the raw EBN. During the cleaning process, the raw EBN is kept in the EBN compartment. A non-abrasive nylon brush will assist in cleaning the EBN surface without causing damage to the microstructure. The brush will clean the specimen for a set time range of 30 seconds, 45 seconds, and 60 seconds in this experiment. The main goal of this experiment is to collect weight data before and after the experiment to calculate the removal rate using Equation 1.

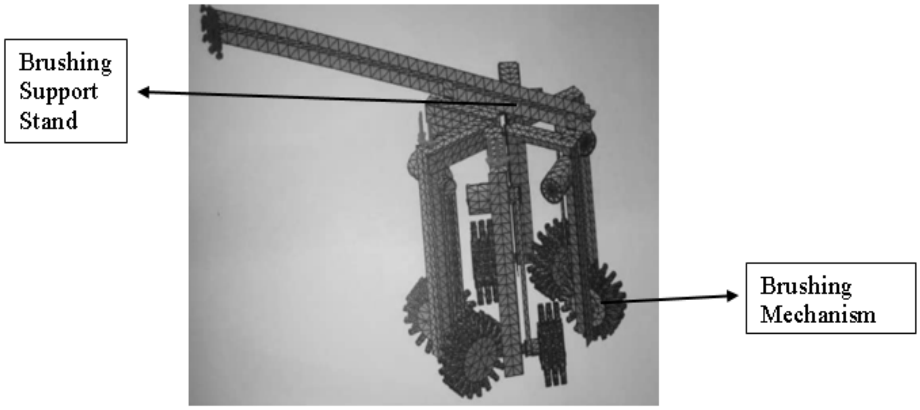

Figure 6. Brushing technique

SOP of Brushing Technique Set Up

In order to execute the experiment correctly, various processes must be identified and followed. The procedure for experimenting is shown in Table 2.

Table 2
SOP of brushing cleaning technique

No	Procedure
1	Prepare three specimens for each experiment.
2	These specimens are placed in the EBN nest compartment.
3	Setting to run the brush for the selected time range.
4	After the running time is reached, remove the EBN from the EBN compartment and place it in a bowl.
5	Take the necessary measurements, such as its weight, after the experiment.
6	The experiment is repeated by using different specimens for the following selected time.
7	Compute the collected data in a Table.

Taguchi Method

The Taguchi Method is an eight-step process for designing, executing, and analyzing matrix experiment data to discover the best amounts of controlling elements. It is necessary to determine the inputs that will influence the outcome. The data of optimized parameters will be analyzed using Minitab 16. System design, parametric design, and tolerance design are the three key stages of the Taguchi technique. General technical knowledge is used in system design. The purpose of parametric design is to enhance parameter sets. Tolerance design is the process of determining the tolerance of optimal parameters. Factors, levels, and reactions are the three main components of the Taguchi Method. Controllable or uncontrolled variables are possible. The study's level is the factor's setting. The experiment's result is the response.

Brushing technique, bubble, and microbubble size are the variables in this experiment. Each of the three factors has its setting at the element level. A non-abrasive nylon circular brush was chosen as the brushing technique. Bubble sizes of 1–2 mm and microbubble sizes of 0.5–100 μm have been chosen. The experiment duration has been set to 30 seconds, 45 seconds, and 60 seconds for both parameters.

Based on the insights gained through engagement with SME, the selected parameters for conducting the Taguchi Method were identified. The signal-to-noise (S/N) ratio was used to examine the optimal parameters for the cleaning mechanism. The formula for calculating the signal-to-noise S/N ratio is shown in Equation 2.

$$\frac{S}{N}\frac{S}{N} = 10 \log \frac{1}{n}\frac{1}{n}\left(\Sigma y^2 \Sigma y^2 \right) \quad \textbf{(2)}$$

Where, y= observe response value;
n= number of replication.

The graph and table will be created using the data collected from the signal-to-noise S/N ratio. The EBN cleaning mechanism's optimal parameters will be displayed. Finally, an analysis of variance (ANOVA) will be used to estimate the contribution of significant parameters to the quality response.

Validation of the Optimized Parameters

Following the optimization of the selected parameters, these parameters will be tested in three separate sequences, each of which includes a different set of cleaning parameters. Then, the cleanliness % will be determined using the result, and the sequence with the highest cleanliness percentage will be chosen. The equation for improvement in the aspect of cleanliness is shown in Equation 3.

$$\text{\% of Cleanliness} = \frac{\text{weight loss (before- after)}}{\text{Total weight loss}} \times 100\% \times 90\% \quad \textbf{(3)}$$

(Taken 10% of loss weightage of EBN is dissolved in water.)

While soaking the raw EBN in water, tiny impurities such as sands and dirt will dissolve in water. The soaking process will also help to remove nitrate content from raw EBN. It will eventually take about 10% of the total weightage of the raw EBN (Cranbrook et al., 2013).

RESULTS AND DISCUSSION

All the experiments were carried out according to the instructions. The studies were carried out to test parameters like bubble, microbubble, and brushing technique. The Taguchi Method is then used to optimize the acquired data. The result of the table and graph will be displayed after the Taguchi Method is completed, and the most optimized parameter set for EBN cleaning will be identified.

Microbubble Cleaning Technique Parameters Setting

The Microbubble Technique has a significant effect on the cleanliness of EBN. The removal rate in terms of cleaning time is discussed. Table 3 shows the most significant efficiency on the cleaning mechanism of microbubble from the experiment, while Figure 7 shows the cleaned EBN specimens using microbubble.

Table 3
Removal rate of EBN based on microbubble technique

Time	30 seconds	45 seconds	60 seconds
Weight of raw EBN (g)	0.71	0.80	0.70
Weight of cleaned EBN (g)	0.70	0.78	0.67
Weight loss (g)	0.01	0.017	0.03
Removal rate (g/min)	$1.00x10^{-2}$	$1.70x10^{-2}$	$3.0x10^{-2}$

Bubble Cleaning Technique Parameters Setting

The bubble technique has a less significant effect on the cleanliness of EBN. The removal rate in terms of cleaning time is discussed. Table 4 shows the most significant efficiency on the cleaning technique of bubble from the experiment, while Figure 8 shows the cleaned EBN specimens using the bubble technique.

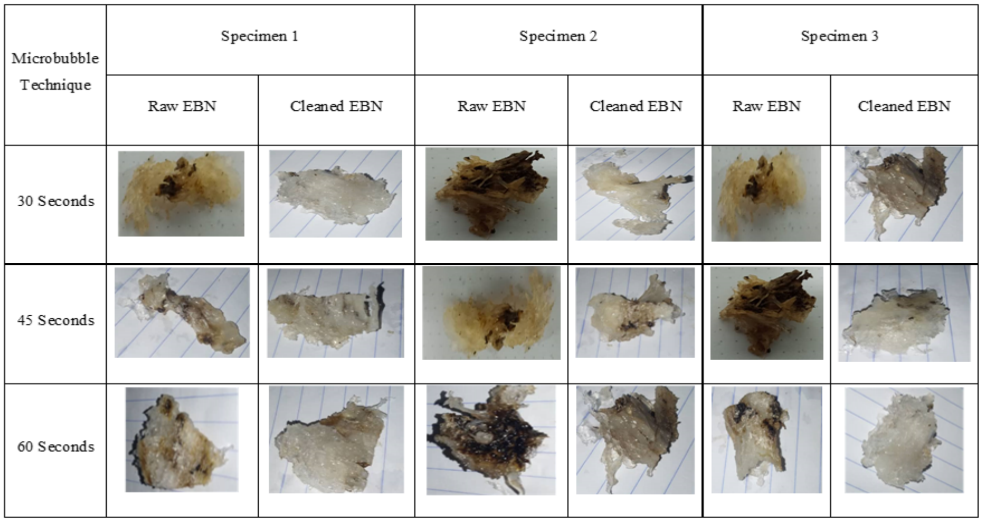

Figure 7. Microstructure of the EBN specimen of microbubble technique

Table 4

Removal rate of EBN based on bubble technique

Time	30 seconds	45 seconds	60 seconds
Weight of raw EBN (g)	0.543	0.72	0.61
Weight of cleaned EBN (g)	0.54	0.71	0.597
Weight loss (g)	0.003	0.007	0.013
Removal rate (g/min)	$3.00x10^{-3}$	$7.00x10^{-3}$	$1.30x10^{-2}$

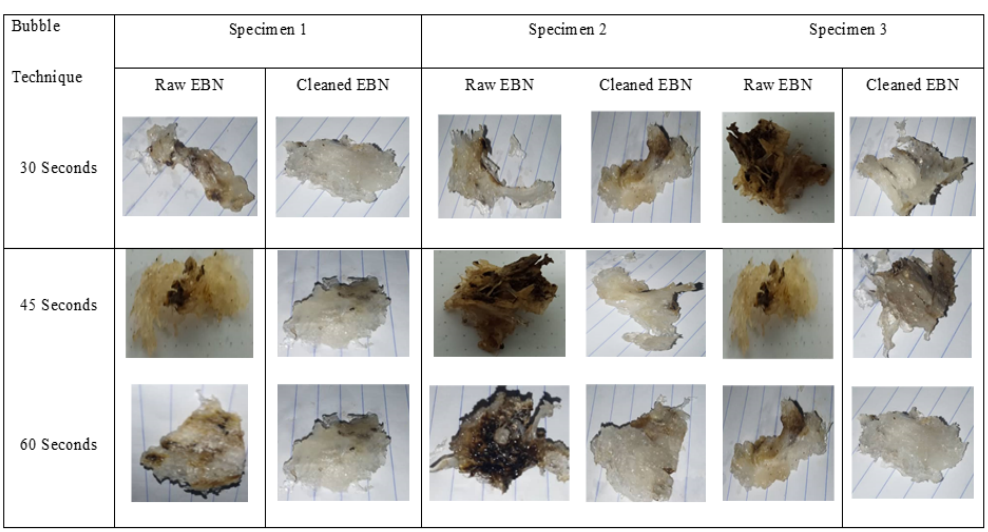

Figure 8. Microstructure of the EBN specimen of bubble technique

Brushing Technique Parameters Setting

The brushing technique is an important parameter set. Table 5 shows the experimental result of the removal rate of EBN, and Figure 9 shows the cleaned EBN specimens using the brushing technique.

Table 5

Removal rate of EBN based on brushing technique

Time	30 seconds	45 seconds	60 seconds
Weight of raw EBN (g)	0.60	0.707	0.843
Weight of cleaned EBN (g)	0.59	0.69	0.81
Weight loss (g)	0.01	0.017	0.033
Removal rate (g/min)	1.00×10^{-2}	1.70×10^{-2}	3.30×10^{-2}

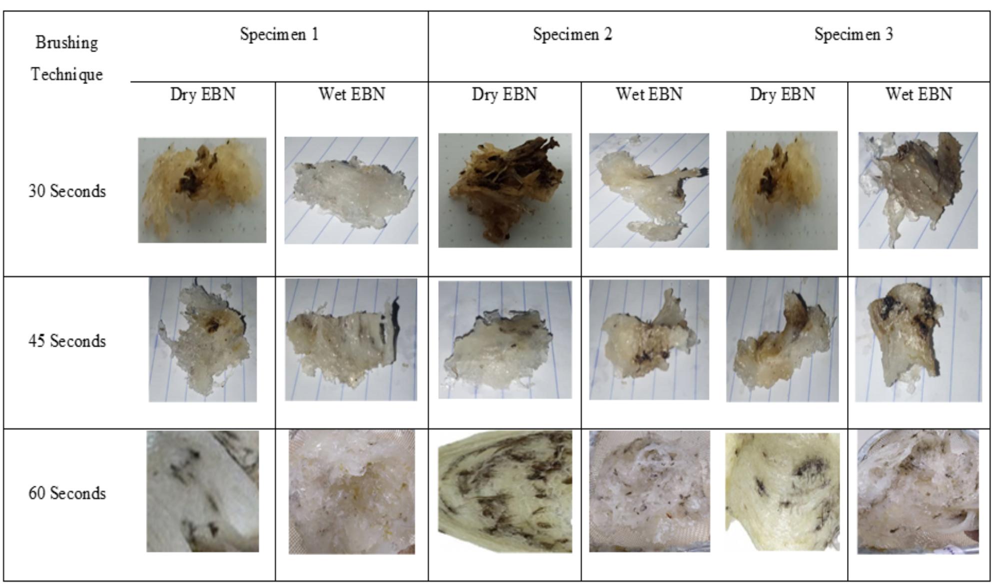

Figure 9. Microstructure of the EBN specimen of brushing technique

Optimization of the Parameters

The optimization of the selected parameters will be carryout using the Taguchi method. The main purpose of using the Taguchi method is to minimize the number of experiments carried out in combinations of the factors that occur in the same number of times. The two factors are the brushing mechanism and microbubble mechanism. These experiments were conducted according to the orthogonal array of L27, which every three differences of level as shown in Table 6.

Table 6

Experimental parameters and levels

Factors	Level 1	Level 2	Level 3
A: Brushing mechanism (Sec)	30	45	60
B: Microbubble mechanism (Sec)	30	45	60
C: Bubble mechanism (Sec)	30	45	60

Table 7

Design summary of Taguchi method

Microbubble	Bubble	Brushing	Removal rate	SNRA 1	Mean 1
30	30	30	0.00825	41.6709	0.00825
30	45	45	0.01175	38.5992	0.01175
30	60	60	0.01975	34.0887	0.01975
45	30	60	0.01650	35.6503	0.01650
45	45	30	0.01425	36.9237	0.01425
45	60	45	0.01425	36.9237	0.01425
60	30	45	0.01825	34.7747	0.01825
60	45	60	0.02000	33.9794	0.02000

Table 8

Response table for signal to noise ratios

Level	Microbubble	Bubble	Brushing
1	38.12	37.37	38.08
2	36.50	36.50	36.77
3	34.80	35.55	34.57
Delta	3.32	1.81	3.51
Rank	2	3	1

Table 7 shows the design summary of the Taguchi Method from the Minitab16 software. Table 8 shows the response for the parameters for EBN cleaning purposes. The delta value in Table 8 shows the difference in response from level 1 to level 3. It also indicates that the higher the value, the higher the influence of the parameter on the cleaning process. The rank shows the importance of each basic parameter.

Validation of the Proposed Parameters Set

Three distinct sequences have been tested to develop the optimal parameters set that can result in the highest cleanliness percentage in the shortest time. Table 9 lists three sequences that can be tested with the time limit. For each sequence, the experiment was carried out. The result has been recorded and is shown in Table 9.

Table 9

Sequence of EBN cleaning process

Sequence 1		**Sequence 2**		**Sequence 3**	
Process	Time	Process	Time	Process	Time
Microbubble	1 min	Bubble	1 min	Brushing	1 min
Brushing	1.5 min	Brushing	1.5 min	Bubble + Microbubble	1 min
Bubble	1 min	Microbubble	1 min	Bubble	1 min
Bubble + Microbubble	1 min	Bubble + Microbubble	0.5 min	Microbubble + Brushing	1.5 min
Bubble + Brushing	1 min	Bubble + Brushing	1 min	Microbubble	1.5 min
Microbubble + Brushing	1.5 min	Microbubble + Brushing	2 min	Bubble + Brushing	1 min
Total time	7 min	Total Time	7 min	Total Time	7 min
Weight (Before)	2.56g	Weight (Before)	2.03g	Weight (Before)	1.88g
Weight (After)	2.31g	Weight (After)	1.88g	Weight (After)	1.72g
Weight Loss	0.25g	Weight Loss	0.15g	Weight Loss	0.16g
After Manual Cleaning	2.22g	After Manual Cleaning	1.78g	After Manual Cleaning	1.64g
Total Weight Loss	0.34g	Total Weight Loss	0.25g	Total Weight Loss	0.24g
% of Cleanliness*	66.18%	% of Cleanliness*	54.00%	% of Cleanliness*	60.00%

The microbubble cleaning technique, bubble cleaning technique, brushing technique, and combinations of these processes at once are all part of the raw EBN cleaning process. By removing contaminants, all these techniques will have a major impact on the cleaning of raw EBN. This technique has been proven successful and efficient in cleaning raw EBN because the EBN will dissolve in a water solution, which may be considered one of its losses; a 10% weight loss will be included in the final computation.

The cleanliness of cleaned EBN for Sequence 1, Sequence 2, and Sequence 3 is 66.18%, 54.00%, and 60.00%, respectively, as shown in Table 9. The highest cleanliness of EBN is Sequence 1, followed by sequence three and sequence 2. From Sequence 1, the first cleaning process, microbubbles, increased the soaking period of raw EBN, allowing the second cleaning technique, the brushing technique, to clean deeper into the dead surface of the raw EBN with seven minutes cleaning time per one piece of EBN.

CONCLUSION

Further research into the characteristics of the cleaning technique will aid in the improvement process. Water absorption and removal rates are critical since they are used in calculations to determine cleanliness and cleaning time. As a result, each parameter (microbubble, bubble, and brushing technique) is tested separately. The Taguchi Method is utilized to discover the best settings for EBN cleaning operations. As a result, the cleaning mechanism of these three cleaning techniques has a cleaning time of seven minutes with cleanliness of 66.18%.

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