DEVELOPING A CLEANING SYSTEM FOR EDIBLE BIRD'S NEST USING TURBULENT FLOW AND ULTRASONIC WAVES

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Raw edible bird's nest (EBN) either from human farming or naturally-harvested can be tainted by fell feathers, dusts of various sizes, fungi and bird feces. For local EBN farmers in Thailand, EBNs are manually cleaned by hand-picking. Due to elaborate cleaning process, experienced labour used approximately eight hours to properly clean three nests, excluding five hours of water immersion. In this work, ultrasonic waves of two frequencies, 37 and 80 kHz, are used together spiral fin, for turbulently stirring the water. An ultrasonic bath has the volume of 6 litres and temperature control is required to prevent EBN from being cooked in the bath. Soaked EBNs are then irradiated with ultrasonic waves for the designated frequencies and duration of ultrasonic exposure with the fin spinning or standing. The cleanliness of the nest is then measured using image processing technique. The taken images are then analysed to acquire the summation of pixel brightness (SPB) as it is used for the visual cleanliness representation. We find that our system improves the visual cleanliness of EBNs up to 30% as compared to those before ultrasonic exposure.
Keywords: Ultrasonic cleaning, Turbulent flow, bird's nest

1. Introduction

Uses of ultrasonic waves in food technology have been developed for decades. They are now widely employed in food industries such as stimulant for living cells or enzyme for effective food production. They can also be utilized for improving extraction and emulsification process, meat and seasoning mixing and ultrasonics in food cleaning [1].

Ultrasonics for cleaning is widely used for non-destructive cleaning of objects such as semiconductors [2], lenses and optical components, jewellery, watches, steel material [3] and musical instrument. In this work, we attempt to design the acoustic system for cleaning EBN.

Typically raw EBNs both farmed and naturally-harvested could be tainted by fell feathers, dust of various sizes, fungi, and bird feces. Cleaning is therefore required. In general, EBNs are manually cleaned by handpicking unwanted substances and the duration of such cleaning process is approximately eight hours for three proper nests by experienced labour force, excluding four to five hours of water immersion of the nest. For cleaning experts, the labour costs about 500 baht per day. Given a small to mid-size bird's nest business, it requires about 30 employees for solely cleaning purpose. The total cost for the cleaning purpose can easily exceed 1.5 million baht a year. Therefore, cleaned EBN is highly expensive. The price can be as high as fifty thousand baht per kilogram

EBN of swiftlets is one of the most expensive agricultural products in the south of Thailand. Thai people consume EBN as they believe that it is a symbol of power and wealth. Such a traditional belief has been reported in ancient medical book since Tang (618-907 AD) and Sung (960-1279 AD) dynasty of China [4]. Without doubt, China, especially Hong Kong, is the country with most EBN importing and consuming on the earth. While North America is coming for the second place. Twenty million nests are the overall amount of EBN consumed due to the record of world consumption [5, 6]. Raw EBN comes from two sources: dedicated farms and natural caves. However, not all swiftlets' nests are edible. Only two genera of swiftlets that their nest is edible, that is, Aerodramus and Collocalia.

There are three genera of swiftlet in Thailand: Aerodramus, Collocalia and Hirundinidae. Only Aerodramus and Collocalia build their nest with saliva. Thailand agricultural product standard 2014 clearly specifies that 4 species in the 2 genera of swiftlet are the producer of EBN. They are Aerodramus germani, Aerodramus fuciphagus, Collocalia germani and Collocalia fuciphagus. Hirundinidae is the genus of swiftlet that builds its nest with saliva and slush, thus its nest is inedible [7].

Swiftlet's nest farming is popular in Thailand, particularly in Pak phanang, Nakhon Si Thammarat. Now such a business is extended out to the east and west of Trat and Petchaboon. Since EBN has attractive market value, farming technique has been continuously improved. Mimicking the farm to be cave-like environment is critical. Humidity, temperature and amount of light must be well-controlled. [8].

EBN has a mass of 8-10 grams that are comparable to body mass of a swiftlet. The length and width of EBN are approximately 7-10 and 3-7 centimeters, respectively. ENB is composed of 66% of protein, 31% of carbohydrate and 3% of other minerals such as magnesium, sodium, and potassium [9].

Farmed EBN can be harvested twice in one spawning. Since swiftlet spends 35 days building the nest, the first nest is harvested on the 24th day. Then the couple rebuilds a new nest within 11-12 days. The second nest is harvested after the new-borns have grown and left the nest. The first harvested nest is usually whiter and cleaner than the second-round nest since the first nest is not used for hatching the egg. Therefore, the first harvested nest yields higher quality and can be sold with exceptional price. However, the second harvested nest is dirty, it contains feathers, dust particles, feces and fungi which are painstaking to clean.

2. Material and methods

2.1 Designing system

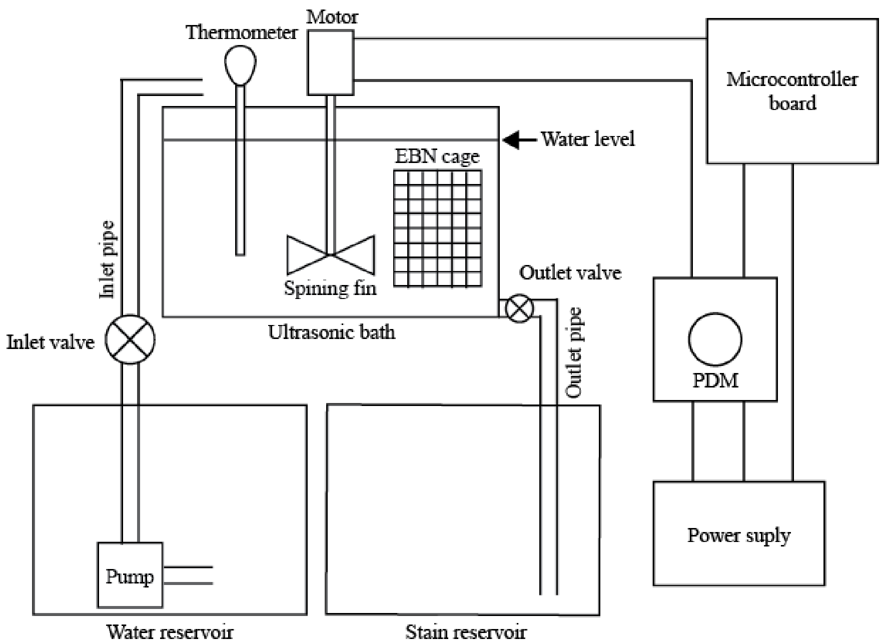

Figure 1: System diagram

The cleaning system has three main parts: ultrasonic bath, turbulent system and water reservoir. Support structure is constructed for mounting those parts together. Ready-made ultrasonic bath, Elma P60H, with dual operating frequency of 37 and 80 kHz and dual modes of sweep and pulse are employed. The ultrasonic bath has the volume of 6 litres and temperature control is needed to prevent EBN from being cooked. An EBN cage is built as a container to keep EBN in the system. The cage is made of metal wires woven to form meshes with the size of 10 mm and 6 mm.

A water reservoir of 50 litres is used for cooling the bath. Water pump with power of 38W and flow rate of 2,000 litres per hour was used to flow water thru a pipe of 18-mm inner diameter into the bath. The water volume is controlled by a valve installed for controlling inlet flow rate. Thermometer is used to monitor the bath temperature. Warm contaminated water from ultrasonic bath is drained through stain reservoir.

Turbulent spinning fin is drawn in a geometrical design software with the purpose of stirring the ultrasonic bath. The fin is 15 cm high including the mounting part and composed of 2 types of paddles: spiral paddle and curved paddle. Spiral paddle is 13 cm high with double helix pattern. The paddle pushes water volume down from the free surface. The curved paddle is 3.5 cm high with elliptical curve of ~0.826 eccentricity and is used to push water volume coming from spiral paddle to the side of ultrasonic bath. Spinning fin is printed with a 3D printer and connected to a 12V DC motor which has a power of 7W and speed of 5,000 rpm. Pulse-duration modulator (PDM) circuit and a microcontroller board is installed for controlling the speed of motor and the operation time. The motor runs with 5-3 seconds on-off. Motor housing is designed to hold a motor above the ultrasonic bath. The housing allows us to move the motor vertically and horizontally, thus the fin can be repositioned as needed.

Figure 2: Designed spinning fin

2.2 Experiments

2.2.1 Experiment I: frequency and mode test

The first experiment is performed using leftover nest form typical cleaning process. The sample is soaked in water for a night to soften and then submerge in ultrasonic bath for 10 minutes without the turbulent system and the containing cage. Since the ultrasonic bath can generate ultrasonic wave at 2 frequencies and 2 operating modes, experimental conditions for each sample are varied for possible combination.

2.2.2 Experiment II: turbulent system and EBN cage test

In the second experiment, extremely dirty EBN is used. EBN sample is soaked in sodium bicarbonate solution with concentration of 15g/L for 4 hours to soften before irradiation with 37 kHz of frequency in pulse mode for 30 minutes. The EBN cage is used as the experimental condition. Turbulent system is applied.

2.2.3 Experiment III: dual frequency test

The third experiment is performed to compare the results between single frequency and dual frequency cleaning. Extremely dirty EBN is soaked in sodium bicarbonate solution of 15g/L for 4 hours similar to that of the 2nd experiment. The first sample is irradiated with frequency of 37 kHz in pulse mode for 30 minutes. The second sample is irradiated with frequency of 37 kHz and then with 80 kHz in pulse mode for 30 minutes. Both samples are contained in 10-mm meshed cage and the turbulent system is applied.

2.3 Cleanliness measurement

The images taken prior and after ultrasonic irradiation of EBN sample are converted to greyscale. Since the EBNs harvested in each season in a year are different in terms of white-yellow colour scale. Such a variation of white-yellow scale of EBN is not related to the cleanliness. Using greyscale image helps eliminating this variation. Fig. 3 shows image of the same EBN sample in (a) colour and (b) greyscale mode.

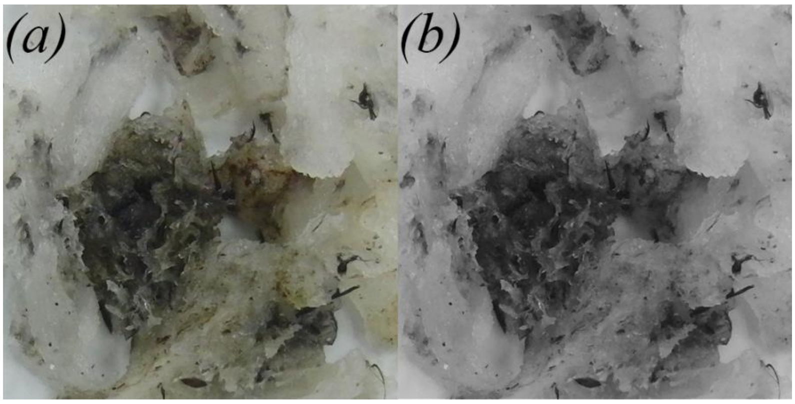

Figure 3: EBN images in (a) colour and (b) grey scale mode

Grey scale image of EBN sample is analysed for brightness levels. Each pixel in the image has possible brightness level ranging from 0 to 1 for ideal dark and the brightest pixel, respectively. Since all images are taken in 8 bit depth mode, so the range of brightness level has dynamic range of 2^8 levels. Thus, summation of each pixel brightness in the image is 0 if the image is completely dark. Otherwise the image is completely bright corresponding to the brightness value of 1 for every single pixel, the summation of pixel brightness is its image dimension. Summation of pixel brightness (SPB) is used to represent the cleanliness of EBN sample. SPB is mathematically defined by:

$$SPB = \sum_{i=1}^{2^n} b_i N_i \tag{1}$$

Where n is image bit depth, b is brightness and N is number of pixel that has a brightness of b. Contamination such as feathers, dust, fungi, and faeces displays as multiple dark spots in the EBN greyscale image which results in small values of SPB. After ultrasonic irradiation, the value of SPB should increase if the sample gets cleaner. SPB together with brightness level histogram allows us to determine if the EBN is cleaner quantitatively.

3. Results and discussion

The system is working together properly. The temperature control system is able to control temperature in the bath to 30 °C while the system is working with full power. The turbulent system is able to generate turbulent flow of water in the bath evenly. Moreover the turbulent system is able to separate rubbish out of EBN cage. The cage helps preventing outlet drainage from clogging up and improving yield weight of EBN after the cleaning process. Greyscale image of EBN sample is then analyzed for brightness histogram. SPB is used for cleanliness comparison.

3.1 Experiment I: frequency and mode test

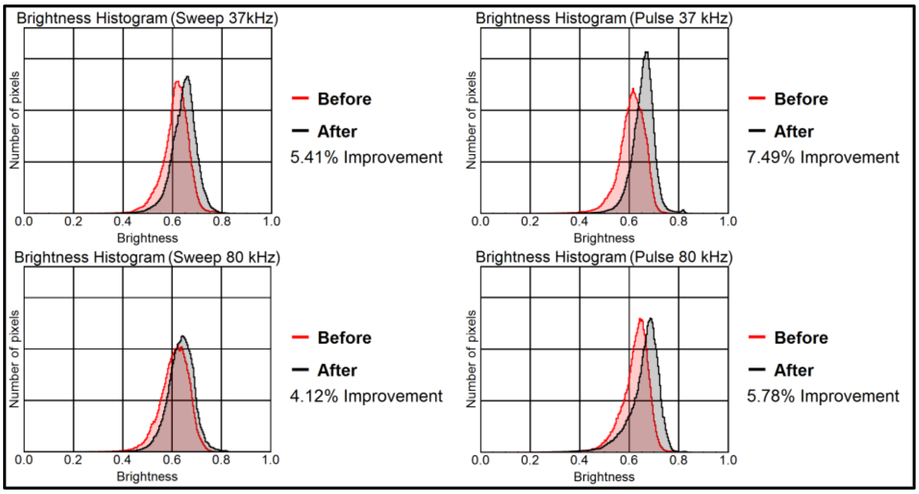

Figure 4: Image brightness histogram for each sample in experiment I

Brightness histogram is illustrated in Fig. 4. The histograms show that EBN samples in this experiment are initially not so dirty, since the histograms of before image have a brightness peak between ~0.6 to ~0.7. Moreover, a steep profile is indicates a small distribution of pixel brightness. After ultrasonic treatment, brightness histograms show a slightly cleanliness improvement since the histogram profiles display right shift to brighter side. Narrower profile is obviously observed for a sample which is treated with 37 kHz in pulse mode.

The ratio of increased SPB after cleaning to that before cleaning represents the cleanliness improvement. From Fig. 4, samples that have been treated with 37 kHz frequency show better cleanliness improvement than that radiated by 80 kHz wave for both pulse and sweep mode. In addition, samples that have been treated with pulse mode have a better cleanliness improvement as compared to that of sweep mode for both 37 and 80 kHz. A 37-kHz wave in pulse mode shows cleanliness improvement of 7.49%. However, the result is not satisfactory.

3.2 Experiment II: turbulent system and containing cage test

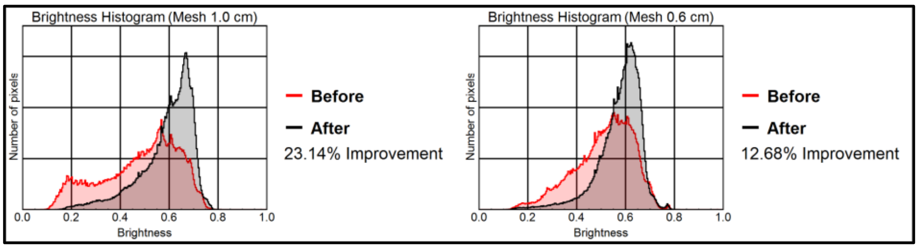

Figure 5: Image brightness histogram for each sample in experiment II

Histograms of pixel brightness in Fig.5 are the result of the 2nd experiment. Before treatment, both samples have a broad profile of distribution and display a brightness peak of ~0.5 to ~0.6. Such a profile indicates that EBN samples are significantly dirty. After ultrasonic treatment, narrow distribution profile is presented in both samples. Decreasing of ~0.1 to ~0.5 brightness pixel are evidently seen in brightness histograms. However, pixel brightness of those samples after irradiation never exceeds ~0.8 of brightness.

SPB is then analyzed to find the improvement. A sample with 10-mm mesh cage has a cleanliness improvement of 23.14% while 6-mm mesh cage yields the cleanliness improvement percentage of 12.68%. Such an experiment shows a better improvement than the 1st experiment.

3.3 Experiment III: dual frequencies test

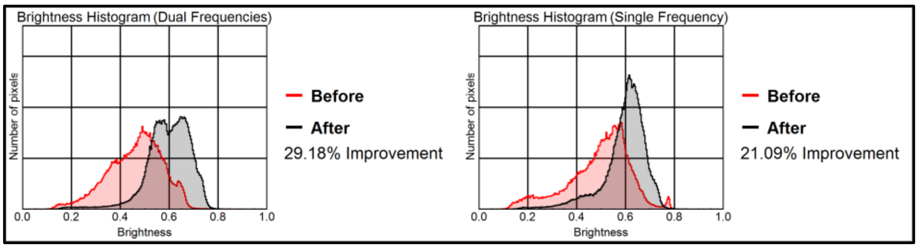

Figure 6: Image brightness histogram for each sample in experiment III

The results of the 3rd experiment are illustrated in Fig.6. Before ultrasonic treatment, histogram of both samples are comparable in brightness distribution and peak. Broad profiles with certain amount of 0.1 to 0.5 brightness pixel are considered a significantly dirty EBN. After treatment, brightness histogram of both samples shows dominant decreases of 0.1 to 0.5 brightness pixels. Especially for dual frequencies treated sample, pixels have a brightness of 0.1 to 0.4 are almost disappeared. In addition, brightness profile of dual frequencies is shown double brightness peaks while single frequency is shown only a peak with higher number of pixels.

Analyzing for SPBs shows cleanliness improvement for each sample and shown in Fig.6. For dual frequency treated sample, 29.18% of improvement is evident while the single frequency treated sample yields the cleanliness improvement of 21.09%.

3.4 Summary

SPB can effectively represent a cleanliness of EBN. Difference of the images taken before and after irradiation in the 1st experiment, as shown in Fig.7, are bleary when observed with naked eyes. However, investigating of SPB gives the ability to identify if the irradiation can improve the cleanliness of EBN samples quantitatively even though a small improvement exists.

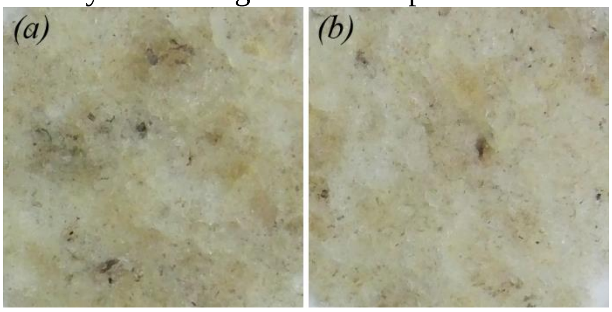

Figure 7: The image taken (a) before and (b) after irradiated with 37 kHz of frequency in pulse mode for experiment I.

Brightness histogram also indirectly represents the amount of contamination in the EBN image. Decreasing in quantity of low brightness pixels and increasing of higher brightness pixels are observed in every experiments. From the 2nd and 3rd experiments, we find that the taken images after irradiation result in lower distributed profile with higher brightness peak amplitude. However, a dual frequency treated sample in the 3rd experiment, double brightness peaks are observed.

Since the cavitation plays important role in ultrasonic cleaning. Radius of such cavitation is inversely depending on frequency; thus, cavitation caused by 37 kHz ultrasonic wave is larger than that of 80 kHz wave [10, 11]. Larger cavitation, which caused by 37 kHz wave, might help cleaning large contamination such as feathers and feces while smaller cavitation helps cleaning smaller contamination such as fungi and dust. Although, 80 kHz ultrasonic waves alone yield unsatisfying result but it can help improving the overall result with dual frequency by getting rid of smaller contamination that 37 kHz waves is unable to clean.

According to experiment II, the turbulent system and the cage effectively improve the cleanliness of the EBN samples. Even though 10-mm meshed container show better improvement but it loses too much EBN during the cleaning process. Cleanliness improvement of 6-mm meshed cage is smaller almost by a half of those 10-mm meshed container.

4. Conclusion

SPB can effectively represent the cleanliness of EBN and allows us to measure and compare EBN samples quantitatively. Using 37-kHz ultrasonics in pulse mode can dominantly clean EBN samples that are significantly dirty with the improvement 7.49% to 23.14% of cleanliness. Dual frequencies of 37 and 80 kHz of ultrasonic wave in pulse mode can improve the cleanliness to 29.18%. Turbulent stirr together with meshed container can significantly improve the cleanliness of EBN samples.

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