Development and Improvement of a Vacuum Fryer and a Centrifugal Deoiling Machine for Deep-Fried Split-Gill Mushroom Production

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Abstract

This study aims to develop a vacuum fryer and a centrifugal deoiling machine for producing deep-fried split-gill mushrooms. The vacuum fryer prototype includes a fryer, oil heater, vacuum pump, and control system, while the deoiling machine features a steel frame, external barrel, centrifugal barrel, and transmission unit. Tests are conducted by frying split-gill mushrooms at 60, 80, and 100 °C for 5, 10, and 15 minutes. The deoiling machine removes oil at three rotational speeds (100, 300, and 500 rpm) and deoiling times (1, 3, and 5 minutes). Results show that the ideal frying condition is 80 °C for 10 minutes, and the optimal deoiling is achieved in 5 minutes at 500 rpm.

Keywords: deep-fried mushrooms, vacuum frying, deoiling, production process

1. Introduction

Vacuum-fried items are becoming more and more popular as a result of consumer desire for nutritious and safe frying products [1]. Nowadays, both small- and large-scale processing enterprises employ vacuum-frying technology to produce goods on a commercial basis. Additionally, it is employed to create novel products using crisp fruits and vegetables [2]. The benefits of using vacuum frying (VF) technology to make crispy, deep-fried split-gill mushrooms include reduced oxygen in the system, which leads to less oxidation of the vegetable oil, and faster water evaporation in the finished products as the vegetable oil is heated below 100 °C.

Moreover, used oil can be reused for a longer period than conventional frying because it retains most of its quality when exposed to normal atmospheric conditions. Because they are equal to their original nature in terms of quality and have an extended shelf life and storage life, processed split-gill mushrooms have a higher value and can generate higher revenue for business owners.

The Split-Gill Mushroom Farming Community Enterprise in Tha Kham Sub-district is one of the major mushroom farming locations in Hat Yai District, Songkhla Province. Due to its health benefits, researchers are interested in using split-gill mushrooms (*Schizophyllum commune*) as a raw material for food and pharmaceutical products [3]. This community enterprise uses a closed greenhouse system with a smart farming control application intended for a closed greenhouse mushroom cultivation system [4] and an automatic spawn block manufacturing system for its mushroom growing [5]. The villagers in the community enterprise make mushroom spawn blocks, steam mushroom spawn blocks, and cultivate

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mushrooms every day after finishing their rubber tapping activities in the morning. During harvest season, middlemen visit the farm to collect fresh split-gill mushrooms. However, with a relatively large amount of fresh split-gill mushrooms available, the villagers process them into various value-added products, such as deep-fried split-gill mushrooms.

Deep-fried split-gill mushrooms are the newest snack made by a group of farmer housewives in this community enterprise, with the assistance and knowledge of academics. The production process of deep-fried split-gill mushrooms involves washing and air-drying to lower the moisture content of fresh mushrooms. The mushrooms are seasoned according to the recipe and then deep-fried over medium heat until they turn orange. They are then taken out to allow the oil to drain for 30 minutes. The deep-fried are weighed and packed into 50-gram portions for later distribution.

The members of this community enterprise learned that the reuse of frying oil rapidly deteriorates its quality and gives it a burnt scent, requiring regular frying oil changes. This is since frying under atmospheric conditions requires high temperatures, which also increases the costs. In addition, the oxygen in the air causes deep-fried split-gill mushrooms to lose quality and shorten their shelf life, which also facilitates the oil conversion to free fatty acids.

Regarding the problems encountered during deoiling, the residual oil in the deep-fried split-gill mushrooms escapes into the container and degrades the quality of the final product. This reduces the shelf life and gives off a rancid scent to the deep-fried split-gill mushrooms, affecting the flavor of the product. The extensive deoiling procedure needed for these deep-fried split-gill mushrooms slows down the packaging process [6] and undermines consumer confidence.

Although split-gill mushroom frying has not been extensively documented in the literature, there is sufficient data to study some relationships in deep-frying. For example, a study showed that higher frying temperatures and longer time resulted in fried banana bracts with higher fat content but lower moisture content. Moreover, different rotational speeds and deoiling times resulted in significant differences in fried banana bracts properties, and the ideal production conditions of fried banana bracts properties were frying at 100 °C for 20 minutes followed by centrifuging at 1,800 rpm for 5 minutes [7].

Studies have been conducted on sonication and microwave treatments for VF to attain ideal frying conditions and enhance the quality of fried products using button mushrooms as a raw material. VF, microwave-assisted vacuum frying (MVF), ultrasound-assisted vacuum frying (UVF), and microwave combined with ultrasound vacuum frying (UMVF) techniques were also used to produce the mushroom chips [8]. The effect of ultrasound on the frying rate and quality of fried mushroom chips (FMC) was investigated using MVF. The higher moisture evaporation rate and lower oil content were achieved at optimum conditions of 1,000 W and 90 °C [9].

In addition, a deoiling machine for shredded pork was developed which consisted of a 900 × 900 × 1,200 mm steel frame, a barrel with an internal diameter of 800 mm and a depth of 500 mm, and a strainer with a diameter of 250 mm and a depth of 25 mm. The rotation of this deoiling machine was driven by a 2 hp electric motor and a 1,800 W blower was used for hot air drying of the shredded pork [10].

The majority of the vacuum fryers used in the studies were large and unsuitable for frying split-gill mushrooms, which are an agricultural product of small size that requires a short frying time. Most of the studies on oil centrifugation focused on vertical centrifugation and found that different product types were affected differently by container size, rotation time, and large barrel rotation speed. Designing and constructing a vacuum fryer and a centrifugal deoiling machine that is suitable for users, raw materials, and final products is therefore crucial to the development of the deep-frying process for split-gill mushrooms.

To enhance the deep-fried split-gill mushroom products, a centrifugal deoiling machine, and a vacuum fryer must be developed. This is done to improve and preserve nutritional value while reducing oil retention. When designing and building these machines, considerations such as the community enterprise’s output capacity, production area, ease of use, and simple operation must be made.

2. Research Methodology

This research presents the design and development of a vacuum fryer and a centrifugal deoiling machine. The test material, split-gill mushrooms, was cultivated by the Tha Kham community enterprise group in Hat Yai District, Songkhla Province. The mushrooms were vacuum-fried at 60, 80, and 100 °C for 5, 10, and 15 minutes. After frying, the mushrooms were placed in a basket set within the centrifugal deoiling machine, which operated at three deoiling times (1, 3, and 5 minutes) and three centrifugal speeds (100, 300, and 500 rpm).

2.1. Vacuum fryer design [11]

The main components of this vacuum fryer included a fryer, an oil heater, a vacuum pump, and a control system. The design was based on the principle of energy balance which was used to determine the quantity of oil and heater power. The base curvature size of the oil heater was intended to resemble that of the fryer. For a uniform temperature distribution, the fryer's heating element was situated at the bottom. This vacuum fryer was 8 mm in diameter, and operates with 2,000 W of electricity, between 80 °C and 130 °C (±2 °C). The fryer was a 2-layer design of 4 mm-thick 304L stainless steel. To support the pot lid and external pressure, the outer layer was a cylindrical barrel with a rim on top. Its dimensions were 300 mm in height and 300 mm in diameter, with a capacity of 30 L for oil.

The inner layer was a cylindrical strainer with a diameter of 250 mm and a height of 250 mm, which collected and filtered the frying debris. The 1/40.25 hp rotary vane vacuum pump used in this fryer's vacuum system delivered a 3 cubic feet per minute (CFM) flow rate at 230 V, 50-60 Hz and this vacuum system produced a maximum vacuum of 150 microns (500-–550 mmHg). The results showed that the scores on the performance test of vacuum-fried mushrooms processed at 80 °C for 10 minutes were as follows: 8.36 ± 1.24 for color, 8.59 ± 1.12 for appearance, 8.70 ± 1.38 for crispness, 8.75 ± 1.28 for odor, 8.60 ± 1.28 for taste, and 8.70 ± 1.28 for overall acceptability, which was higher compared to all other treatments. Each of these components, as shown in Fig. 1, was housed inside the machine for easy and convenient transportation and operation.

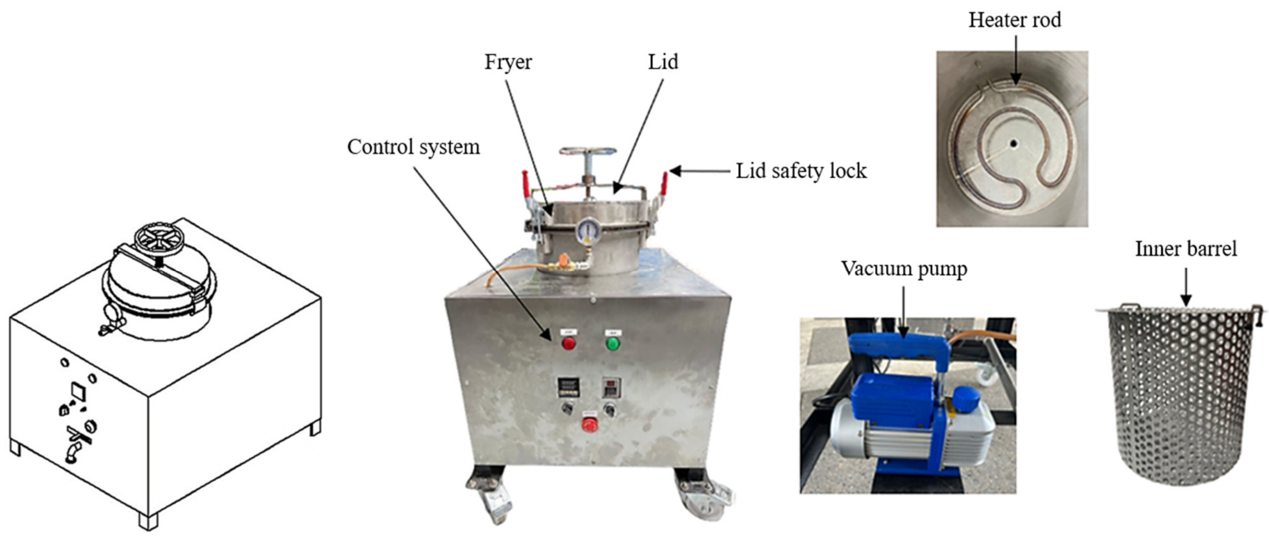


Fig. 1 Vacuum fryer

2.2. Design of a centrifugal deoiling machine [12]

In this study, a centrifugal deoiling machine with a good operation mechanism and efficiency for the production of deep-fried split-gill mushrooms in the community enterprise was developed based on the examination of issues and information. The four primary components of this centrifugal deoiling machine were as follows:

(1) A rectangular stainless-steel frame with a 360 × 360 mm base and a height of 560 mm from the base equipped with anti-vibration rubber feet pads.

(2) A 360 mm diameter by 370 mm high external cylindrical stainless-steel barrel with carrying handles and a drain hole.

(3) A 250 mm diameter by 200 mm high centrifugal cylindrical barrel made of perforated stainless steel. The perforations were 5 mm in diameter. The motor shaft was held in place by a shaft at the bottom of the barrel. It contained an anti-vibration support and a motor balancing system.

(4) A 500 W 24V DC brushless motor-driven gearbox unit with a speed range of 0-1,000 rpm.

As shown in Fig. 2, a control box was used to rotate the motor clockwise, which regulated the rotational speed of the gearbox unit.

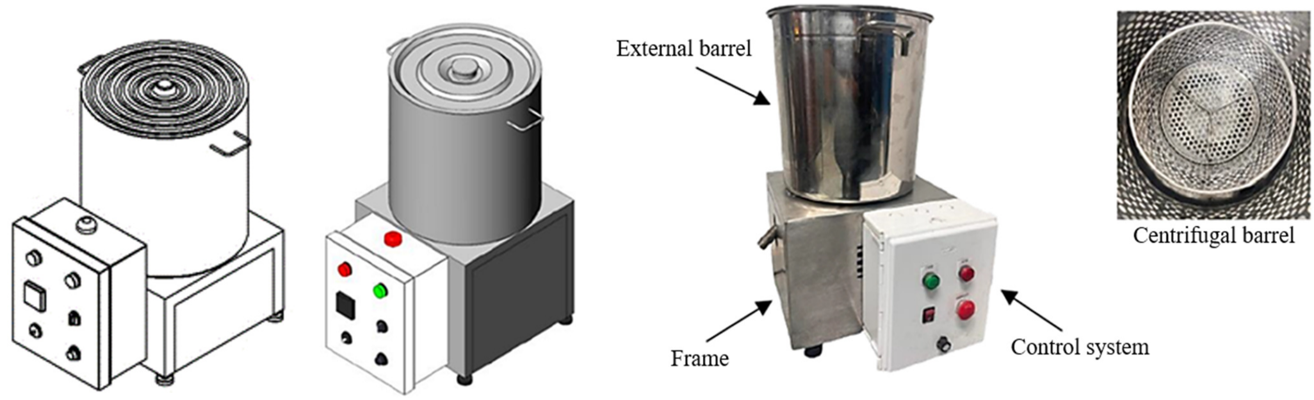


Fig. 2 Centrifugal deoiling machine

2.3. Materials and preparation

Split-gill mushrooms, which grow to a size of 2-3 centimeters and take 7-8 days to mature, used in this study were grown by the Split-Gill Mushroom Farming Community Enterprise in Tha Kham Sub-district, Hat Yai District, Songkhla Province. The split-gill mushrooms were harvested, cleaned with clean water, and separated from their bunches. They were then submerged in room temperature water for one hour and allowed to drain.

2.4. Experimental design

In a vacuum fryer, split-gill mushrooms were cooked for 5, 10, and 15 minutes at 60, 80, and 100 °C with a maximum vacuum of 150 microns. Deep-fried split-gill mushrooms were packed and sealed in polypropylene (PP) bags and placed at room temperature for an hour. The centrifugal barrel of a deoiling machine was then filled with one thousand grams of deep-fried split-gill mushrooms. Oil removal tests were performed at 3 deoiling times (1, 3, and 5 minutes) and 3 rotational speeds (100, 300, and 500 rpm). The weight of the deep-fried mushrooms was recorded and utilized in further analysis.

2.5. Performance tests

(1) Volume and weight before and after deep-frying

The tests were performed by weighing the drained split-gill mushrooms to three decimal places on a digital scale, and the results were recorded as weight before deep-frying. Deep-fried split-gill mushrooms were weighed and the results were reported as weight after deep-frying. The volume and the ratio of fresh weight to dry weight were computed using the weights obtained both before and after deep-frying.

(2) Deep frying temperature

The temperature of the oil used in deep-frying was measured using a thermocouple installed inside the vacuum fryer which reads the oil temperature measurement results from the start of the frying process until the end of the frying time.

(3) Sensory analysis

Sensory analysis of the deep-fried mushrooms was performed by evaluating preferences for appearance, aroma, taste, crispness, and overall liking using the 9-point hedonic scale. The test group consisted of 30 students from Rajamangala University of Technology Srivijaya, 10 mechanical engineering personnel, 10 food engineering personnel, and 10 food and nutrition engineering personnel, totaling 60 people.

(4) Satisfaction with machine operation

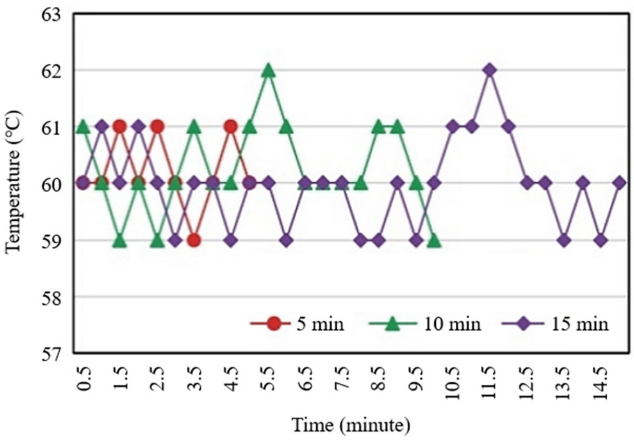
At the Split-Gill Mushroom Farming Community Enterprise in Tha Kham Sub-district, Hat Yai District, Songkhla Province, the use of the centrifugal deoiling machine and the vacuum fryer was used to gauge user satisfaction with machine operation. The following aspects were covered in the satisfaction with machine operations survey: easy operation, machine size and appearance, operational safety, machine usability, operational control, and convenience. Twenty members of the Split-Gill Mushroom Farming Community Enterprise in Tha Kham Sub-district, Hat Yai District, Songkhla Province were the target group. The scores on each aspect were ranked in descending order.

3. Results and Discussion

The research results and analysis focus on evaluating the performance of the vacuum fryer and centrifugal deoiling machine, examining several critical factors. These include measurements of weight before and after frying, oil temperature during frying, and the effectiveness of the centrifugal deoiling machine in processing crispy split-gill mushrooms. The study further investigates the optimal centrifugal speed relative to deoiling duration and conducts an analysis of variance (ANOVA) to assess the statistical significance of the results. Additionally, it includes Hunter Lab color measurements to assess color consistency and evaluate the physical properties of the fried mushrooms. Finally, the study captures user satisfaction with the machine's operation, providing a comprehensive assessment of both functional performance and user experience.

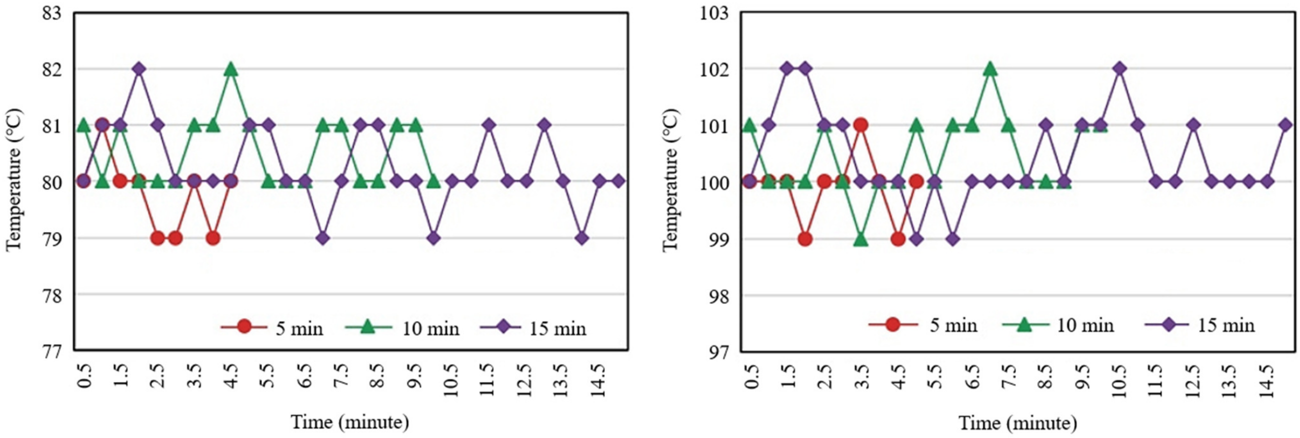
3.1. Volume and weight before and after frying and deep-frying temperature

Table 1 displays the volume, weight, and deep-frying temperature before and after deep-frying. The split-gill mushrooms that were fried for 15 minutes at 100 °C showed the greatest weight loss of 1.25, and dry weight to fresh weight ratio of 1:4.0. The split-gill mushrooms that were fried for 5 minutes at 60 °C showed the greatest weight loss of 2.75, and dry weight to fresh weight ratio of 1:1.8. Furthermore, the average error of the deep-frying temperature from the target temperature was less than 1 °C. The deep-frying temperature of 60 °C displayed the least error of ±0.57 °C, while the greatest error of ±0.79 °C, was recorded at 60 °C, as shown in Fig. 3.



(a) 60 °C

Fig. 3 Deep-frying temperatures



(b) 80 °C (c) 100 °C

Fig. 3 Deep-frying temperatures (continued)

As shown in Table 1, the results are consistent with the literature [13] that claims that a vacuum fryer is a machine that uses oil as the heat exchange medium and vacuum evaporation to minimize the moisture content of food. This machine can reduce the humidity of the product. The results are also consistent with the literature [14] that found that products produced by VF have lower moisture contents than goods produced by regular pressure cooking. Furthermore, compared to the previous literature [15], which found a temperature variation of 5 °C, the deep-frying temperature of the mushrooms in the vacuum fryer developed in this study exhibited less variance. This would undoubtedly impact the manufacturing process and the quality of the final products.

Table 1 Volume and weight of mushrooms before and after frying and deep-frying temperature

Temperature (°C)	Time (minutes)	Mushroom weight			Frying temperature (°C)
		Before (kg)	After (kg)	Dry weight: Fresh weight	
60	5	5	2.75	1:1.8	61.20±0.63
60	10	5	2.30	1:2.1	60.25±0.79
60	15	5	2.45	1:2.0	59.97±0.76
80	5	5	2.20	1:2.2	79.80±0.63
80	10	5	1.80	1:2.7	80.55±0.60
80	15	5	2.00	1:2.5	80.27±0.69
100	5	5	2.05	1:2.4	99.90±0.57
100	10	5	1.30	1:3.8	100.45±0.69
100	15	5	1.25	1:4.0	100.43±0.77

3.2. Performance tests of centrifugal deoiling machine for deep-fried split-gill mushrooms

Results of performance tests of the centrifugal deoiling machine for deep-fried split-gill mushrooms aiming to determine the oil content after the deoiling process for deep-fried split-gill mushrooms produced at 3 rotational speeds (100, 300, and 500 rpm) and 3 deoiling times (1, 3, and 5 minutes) are as shown in Fig. 4.

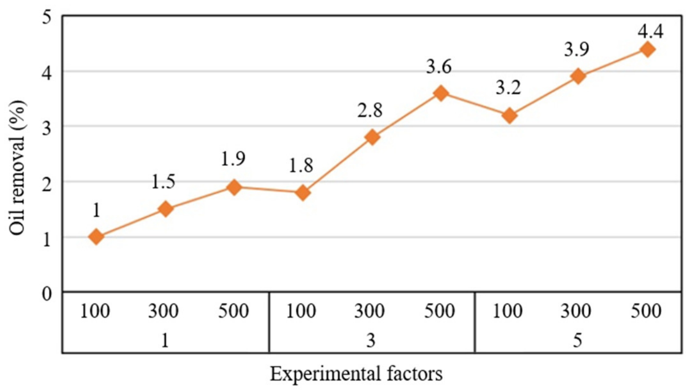


Fig. 4 Oil content of split-gill mushrooms after deoiling

The results of the deoiling experiments in Fig. 4 show the oil content of deep-fried split-gill mushrooms was affected by both the deoiling time and rotational speed. Higher rotational speeds and longer deoiling times reduced the oil content in deep-fried split-gill mushrooms. At a rotational speed of 100 rpm and a deoiling time of minutes, the highest oil content was 3.2%. At a rotational speed of 300 rpm and deoiling time of 5 minutes, the highest oil content was 3.9%. At a rotational speed of 500 rpm and deoiling time of 5 minutes, the highest oil content was 4.4%. The less oil content in fried food, the better the quality of the food and the longer its shelf life.

3.3. Optimum rotational speed and deoiling times

Fig. 5 shows the findings of the experiments conducted to determine the optimum rotational speed at three different rotational speeds (100, 300, and 500 rpm) by weighing the deep-fried split-gill mushrooms once every minute until the weight remained constant.

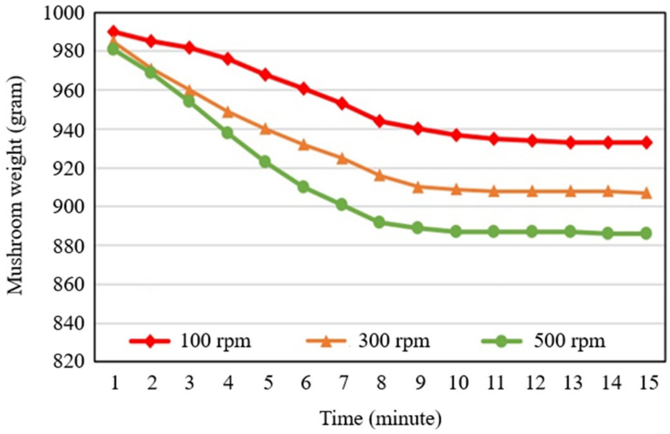


Fig. 5 Optimum rotational speed at different deoiling times

As shown in Fig. 5, at 100 rpm, the weight was 933 grams following the deoiling process for 15 minutes and remained steady after 13 minutes with no further reduction. Therefore, the optimum deoiling time at 100 rpm was 13 minutes. At 300 rpm, the weight was 907 grams following the deoiling process for 15 minutes and remained steady after 10 minutes with no further reduction. Therefore, the optimum deoiling time at 300 rpm was 10 minutes. At 500 rpm, the weight was 886 grams following the deoiling process for 15 minutes and remained steady after 9 minutes with no further reduction. Therefore, the optimum deoiling time at 500 rpm was 9 minutes.

Moreover, the oil content of general fried foods ranges from 10% to 40% [16]. According to the results, an experiment at a rotational speed of 500 rpm and a deoiling time of 9 minutes provided a value within this range, namely 11.4%. The other two experiments, which were performed at rotational speeds of 100 and 300 rpm, showed oil contents of 6.7% and 9.3%, respectively, which were not within the recommended oil content for fried food. This deoiling machine has a maximum capacity of 3 kilograms of deep-fried mushrooms and a cycle time of 10 minutes which is equivalent to a maximum production capacity of 18 kilograms per hour. This is consistent with the literature [17] that suggested that the deoiling process of fried food products depended on various factors, including the type of product, deoiling time, and rotational speed. It also depends on the producer and how much value the quality of that type of fried food requires.

This is consistent with the literature [18] that suggested that a deoiling machine for fried food could reduce the oil content remaining in fried food efficiently. In addition, the results are consistent with the literature [19] which suggested that the reduced oil content after the deoiling process led to longer shelf life, less moisture, and a decrease in rancidity. In this study, the deoiling machine had a maximum capacity of 3 kilograms of deep-fried mushrooms and a cycle time of 10 minutes equivalent to a maximum production capacity of 18 kilograms per hour, and produced deep-fried mushrooms with 11.40% oil content.

3.4. Analysis of variance (ANOVA) results

The ANOVA of the centrifugal deoiling machine for deep-fried split-gill mushroom production was conducted to compare the effects of rotational speed and time on oil removal at 3 rotational speeds (100, 300, and 500 rpm) and 3 deoiling times (1, 3, and 5 minutes). The results are shown in Table 2.

Table 2 Analysis of variance for centrifugal deoiling machine

Source	DF	SS	MS	F	P
Rotation speed (rpm)	2	778.30	389.15	102.55	0.000
Time interval (minutes)	2	2523.63	126.81	332.53	0.000
Error	22	83.48	3.79	-	-
Total	26	33.85.41	-	-	-
S = 1.94798		R1-Sq = 97.53%		R2-Sq(adj) = 97.09%	

From the analysis of oil removal under different conditions shown in Table 2, the coefficient of determination R2 was 97.09%. This implies that the experimental variation due to controllable factors such as tools and equipment was 97.09%. The remaining variation due to uncontrollable factors was 2.91%. Therefore, this experimental design is acceptable as R2 was higher than 70%. Both rotational speed and deoiling time had significant effects on oil removal, with a P-value of less than 0.05, and is believed to have a direct effect on oil removal.

3.5. Color measurement using HunterLab

The results of color measurement using the HunterLab system are shown in Table 3. It was found that split-gill mushrooms fried at 60 °C for 10 minutes had the highest brightness (L*) value of 73.51 ± 0.65 and that split-gill mushrooms fried at 100 °C for 15 minutes had the lowest L* value of 51.64 ± 0.98. For redness (a*), split-gill mushrooms fried at 100 °C for 15 minutes showed the highest a* value of 9.85 ± 0.68 and that of split-gill mushrooms fried at 80 °C for 5 minutes was 5.35 ± 0.86. For yellowness (b*), split-gill mushrooms fried at 60 °C for 5 minutes showed the highest b* value of 25.42 ± 0.47 and that of split-gill mushrooms fried at 80 °C for 10 minutes was 14.26 ± 1.61.

Table 3 Color measurement using the HunterLab system

Temperature (°C)	Time (minutes)	Color values		
		Brightness (L*)	Redness (a*)	Yellowness (b*)
60	5	71.18 ± 1.95	8.63 ± 1.58	25.42 ± 0.47
60	10	73.51 ± 0.65	7.15 ± 0.21	19.29 ± 2.40
60	15	72.32 ± 1.48	6.58 ± 0.28	15.88 ± 2.27
80	5	66.68 ± 2.63	5.35 ± 0.86	22.75 ± 1.23
80	10	68.56 ± 2.04	7.64 ± 0.23	14.26 ± 1.61
80	15	69.47 ± 1.23	6.83 ± 1.16	19.47 ± 0.79
100	5	55.88 ± 4.32	7.16 ± 3.83	25.02 ± 3.57
100	10	53.95 ± 3.32	7.95 ± 2.67	16.45 ± 2.45
100	15	51.64 ± 0.98	9.85 ± 0.68	16.66 ± 1.47

According to the results shown in Table 3, split-gill mushrooms fried at 60 °C for 10 minutes had the highest L*. This was because there was a high heat exchange between the oil and the mushrooms due to the low frying temperature and short frying time. On the other hand, the split-gill mushrooms fried for 15 minutes at 100 °C showed the lowest L*. This resulted from overly high frying temperatures and long frying time, which increased heat exchange. This is consistent with the literature [20] that discovered that more heat exchange occurred at higher frying temperatures. It also aligns with the literature [21] that found that frying at a higher temperature and for a longer period reduced L*.

3.6. Physical characteristics of deep-fried split-gill mushrooms

Fig. 6 shows the physical characteristics of deep-fried split-gill mushrooms obtained at the optimum rotational speed for three different rotational speeds (100, 300, and 500 rpm) by weighing the deep-fried split-gill mushrooms once every minute until the weight remained constant.

(a) 100 rpm (b) 300 rpm (c) 500 rpm

Fig. 6 Physical characteristics of deep-fried split-gill mushrooms at different rotational speeds

It is evident from the physical characteristics of the deep-fried split-gill mushrooms in Fig. 6 that the deep-fried split-gill mushrooms were less stable at greater rotational speeds. When the physical characteristics of the deep-fried split-gill mushrooms processed at rotational speeds of 100 rpm and 300 rpm were compared, it was evident that the mushrooms could not hold their shape and instead appeared clumped together into clusters. However, the deep-fried split-gill mushrooms loosen and become easier to detach from the clusters after being left for a while before being packed into the bags. Furthermore, based on the physical characteristics of deep-fried split-gill mushrooms following the deoiling process, it was discovered that samples of these mushrooms could be kept for a month without oil exuding and no rancid, and remained intact.

3.7. Satisfaction with machine operation

The survey of satisfaction with the vacuum fryer and deoiling machine developed in this study was conducted with 30 members of the Split-Gill Mushroom Farming Community Enterprise in Tha Kham Sub-district, Hat Yai District, Songkhla Province. The results are shown in Table 4.

Table 4 Satisfaction with the operation of the deoiling machine

Aspect	Score	Rank
Easy and straightforward operation	4.80	2
Machine size and appearance	4.50	3
Operational safety	4.20	5
Machine usability	4.30	4
Operational control	4.20	5
Convenience	4.90	1
Mean	4.48	-

From Table 4, convenience showed the highest score with an average score of 4.90, followed by easy and straightforward operation with an average score of 4.80, machine size and appearance with an average score of 4.50, machine usability with an average score of 4.30, and lastly, operational safety and operational control with an average score of 4.20. The respondents showed the highest level of overall satisfaction with the operation of the deoiling machine for deep-fried split-gill mushrooms with an average score of 4.48. The results of the satisfaction survey on the operations of the vacuum fryer and the centrifugal deoiling machine, conducted with a target group of 30 experts comprising 10 mechanical engineers, 10 food engineers, and 10 food and nutrition specialists, are shown in Table 5.

From Table 5, convenience showed the highest score with an average score of 4.50, followed by machine usability with an average score of 4.40, operational safety with an average score of 4.30, operational control with an average score of 4.25, machine size and appearance with an average score of 4.20, and lastly, easy and straightforward operation with an average score 4.15. The respondents showed the highest level of overall satisfaction with the operation of the deoiling machine for deep-fried split-gill mushroom production with an average score of 4.30. The vacuum fryer machine costs 55,000 baht with a break-even point of 8 months, while the centrifugal deoiling machine costs 40,000 baht with the same break-even point of 8 months.

Table 5 Expert satisfaction survey on vacuum fryer and deoiling machine

Aspect	Score	Rank
Easy and straightforward operation	4.15	6
Machine size and appearance	4.20	5
Operational safety	4.30	3
Machine usability	4.40	2
Operational control	4.25	4
Convenience	4.50	1
Average score	4.30	-

4. Conclusions

The vacuum frying machine is a device that utilizes oil as a heat transfer medium and applies vacuum evaporation to reduce the moisture content in food and the final product. The centrifugal deoiling machine is designed to reduce the residual oil content in fried foods. Spinning off the excess oil, extends the product's shelf life and helps reduce rancidity.

The physical characteristics of crispy fried split-gill mushrooms subjected to centrifugal oil spinning show that increasing the spinning speed reduces the product's ability to retain its original shape. According to the development and improvement of a vacuum fryer and a centrifugal deoiling machine for vacuum deep-fried split-gill mushroom production, the optimum production conditions are a frying temperature of 80 °C for 10 minutes and the deoiling rotational speed of 500 rpm for 5 minutes.

The vacuum fryer has been filed for a Thai patent under application number 2303002416, submitted on August 30, 2023. Additionally, the centrifugal deoiling machine has been filed for a patent under application number 2303003606, submitted on December 7, 2023. Both are intended for commercial utilization.

Acknowledgments

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Conflicts of Interest

The authors declare no conflict of interest.

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