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Process Optimization of Vacuum Fried Rice-Straw Mushroom (*Volvariella Volvacea*) Stem Chip Making

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Abstract: The study was aimed to obtain the optimum conditions for vacuum frying and predicting the moisture lost during rice straw mushrooms stem chip production. The raw materials were obtained from the local farmer around the campus. A completely randomized factorial experimental design and Duncan's multiple range tests were used to achieve the objectives. Three temperatures, i.e. 80, 90 and 100 °C and five frying time, i.e. 3, 6, 9, and 15 minutes with a 2 mm slice thickness were studied to determine the optimum condition and predict the moisture decrease. Results showed that the vacuum frying time in general affects the chips color and oil uptake significantly ($p < 0.01$) and correlated with the moisture decrease. The chips moisture content decline significantly after vacuum frying at 90 °C and 100 °C for 3 minutes. While for the 80 °C vacuum frying, the significant decrease of moisture occurred due to the increase of vacuum frying time from 3 to 6 minutes ($p < 0.01$). The optimum conditions for a 2 mm slice thickness chips making are vacuum frying at 100 °C for 3 minutes. The chips moisture lost followed generally a two-stage of falling rate pattern during vacuum frying, and each could be well predicted by an exponential equation ($R^2 = 0.99$).

Key words: Fried rice straw, moisture lost, process optimization, vacuum frying.

1. Introduction

Vacuum fried products of fresh fruits have long been of our research focus since 1994. There was no previous work dealing with mushroom stipe which commonly became mushroom industrial waste. Most of the previous researches were focused on fruits and some other kind of vegetables [1]. This research is intended to render comparative and competitive advantages of vacuum frying technology while lowering the damages of the functional compounds of straw mushroom as compared to other conventional fried snack technology [1], or hydrothermal cooking [2]. Vacuum frying technology offered various advantages to add values of the straw mushroom industrial waste. Vacuum frying techniques have gained enormous popularity in the small-medium scale snack industry due to many reasons. For instance, product performance excellences, such as ability to maintain original fresh flavor and color, wholesomeness and crispness of the fried products while maintaining beneficial substances of the raw materials due to its low temperature frying. The low cost technology was developed based on phase transformation principles of triple point diagram of water. In many cases some improvements on texture and micro structuring techniques were developed based on engineering principles: i.e., rapid evaporation or sublimation of moisture off of a product at temperature below 100 °C will be able to retain not only the original color of the fresh fruits but also the flavor while reduces the amount of oil the food absorbs and minimizes the hazardous chemical reactions to occur during vacuum frying when compared to the traditional frying methods [1]. More efficient use of frying oil was reported by some local industries that utilized the frying oil for 200 batches of vacuum frying processes without noticeable rancidity or off-flavor development when the temperature of vacuum frying processes was below 90 °C. The

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resulted vacuum fried fresh fruits generally have crispy texture, vivid original color and rich in fresh fruits flavor [3]. The commercial vacuum fried fruit products have been developing rapidly and flooding Indonesian snack foods market since early 2000. Various vacuum fried fruit products produced domestically were tough competitors to the imported freeze dried fruits products in the snack markets. Five kind of domestic vacuum fried fruit products most commonly available in the market nowadays are jackfruits chips, pineapple chips, mango chips, snake fruit chips, apple fruit chips. Other starchy fruit chips usually are processed cheaper in the country using conventional deep-fat frying technology after the fruits were sliced and dried. Some other fruit chips were more challenging to produce, such as guava and sawo (*Achras zapota*, L.), due to the presence of stone cells [4]. Researches on heat and mass transfer of vacuum frying process were still very limited. Most of the researches on mass and heat transfer were dealing with immersion frying [5, 6], pan frying, and deep fat frying [7-10] or baking [11]. These technologies have caused considerable amount of functional properties of the fresh foods. Likewise, the research on moisture distribution and time relationship of vacuum frying was also limited. However, previous researches on time-temperature distribution during drying and frying were considerably good to provide underlying phenomena or understanding for the study on vacuum frying. For instance, studies on the logarithmic relationship between the dimensionless ratios of equilibrium moisture content, i.e. rate of moisture removal and time during frying of sausages that was developed based on cereals drying [12] has led [10] to finding a semi empirical equation as shown in Eq. 1.

$$(M - Me)/ (Mi - Me) = A \exp (bt) \qquad (1)$$

where, M is the average moisture content at time t, Me is the equilibrium moisture content, and Mi is the initial moisture content, A is the lag factor of moisture distribution and *b* is the coefficient of frying. Further studies on the application of equilibrium moisture content model on the falling rate stages model of cereals drying [5, 6] confirmed the applicability of the Eq. 1 principles. Similar relationship studies on the use of the dimensionless ratio of temperature distribution and time on frying were carried out by Ref. [10] resulted in Eq. 2

$$(T\text{-}Ta)/(Ti\text{-}Ta) = A \exp (bt) \qquad (2)$$

where, T is the temperature of the material at time t, and Ti is the initial temperature of material at time t, A is the lag factor of the temperature distribution and b is the frying coefficient. Some researchers suggested that water and vapor were escaped from intercellular or capillary space of materials during frying and subsequently or simultaneously replaced by hot frying oil [1, 10]. These equations have provided strong basis for the study on rice straw mushroom chips making. Rice straw mushroom (*Volvariella volvacea* L.) is one of the edible mushrooms widely cultivated in Asia. *Volvariella volvacea* L., also known as straw mushroom, is a member of Amanitacea family that has most preferable taste, flavor and contained high nutritive value [13, 14]. This research was carried out as a part of our first serial researches on vacuum fried vegetable along with white yam. The rice straw mushroom (stipe base) stems were chosen due to its unique meaty flavor and the fact that the peeled straw mushroom canning factories are only interested in the upper stems and the cap while the stipe base parts were abandoned.

2. Objectives

Objective of this research is to obtain optimum vacuum frying conditions and predicting the moisture loss during rice straw mushroom's stem (stipe base) chip making.

3. Materials and Methods

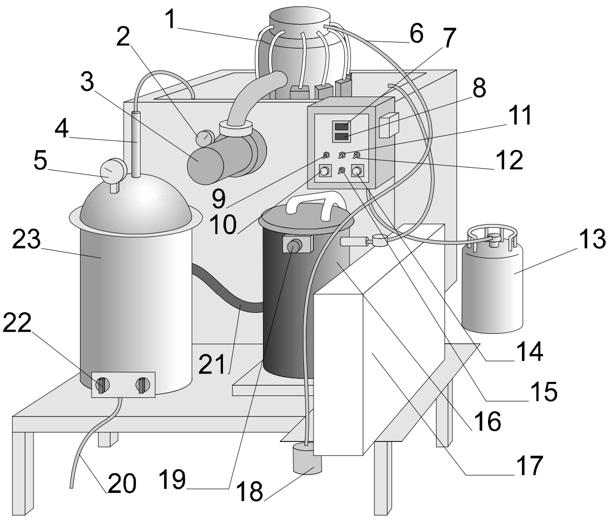
The rice straw mushroom was obtained from the local grower in surrounding IPB Campus Darmaga. The mushrooms were harvested, trimmed, washed and cut the (stipe-base stem) parts of the mushroom into 2 mm thickness. The frying oil was the commercial refined bleached palm oil (PT Intiboga Sejahtera plastic canned 16.5 kg). All chemicals for proximate analyses such as sodium hydroxide, hydrochloric acid, boric acid, petroleum ether, phenolphthalein, dextrin DE 1.725, 97.4% gelatinized starch, and some other chemicals for analyses are all p.a. quality. Some instruments for measurement were analytical balance, T-type thermocouple with recorder (Omega OM-550), Chroma meter (Minolta CR-200, Japan). Vacuum fryer with principal components of frying tank (height × diameter = 0.58 × 0.496 m), condenser, gas burner, frying basket, water jet-pump, temperature, pressure and hydraulic control system (Fig. 1), a fried product oil separator (0.45 m diameter; 510 rpm speed). The vacuum frying process consisted of steps, i.e. straw mushroom selection (only use those with diameter of 2-4 cm) to ensure its uniformity, trimming, washing, slicing, some treatments, frying, draining and centrifugation, and analysis.

3.1 Composition of Rice Straw Mushroom

All proximate analyses but carbohydrate content were undertaken using official methods of analysis of AOAC [14]. Moisture content was determined using AOAC method 930.04. Protein content was calculated based on a conversion factor of 6.25 of the total nitrogen (AOAC Official method 978.04). Fat content was determined using soxhlet extraction method (AOAC Official method 930.09) and crude ash content was determined using standard AOAC Official method 930.05.

3.2 The Bubble End Point and Temperature Profile

Temperature of the rice straw mushroom stem chips during vacuum frying were monitored using a type T thermocouple which was previously calibrated with mercury thermometer. The tip of the thermocouple was inserted in the center part of the chips samples. The vacuum fryer tank was heated first to reach the targeted temperature before frying the rice straw mushroom stem. As soon as oil temperature reached the targeted temperature, the rice straw mushroom was placed inside the frying basket and then the tank is closed to reach the targeted vacuum pressure of 6 mmHg, and started to fry. The end point of vacuum frying was determined by the disappearance of bubble called bubble end point [2, 11].



Legend:	
1.	Water jet vacuum system and tank
2.	Pressure gauge
3.	Water jet pump and tank
4.	Hydraulic system to lift/dip product
5.	Vessel’s vacuum pressure gauge
6.	Condensate tubing
7.	Frying oil temperature reading
8.	Frying oil temperature setting
9.	On-off frying temperature control
10.	Up-lift time control of frying bucket
11.	On-off switch of the air conditioner
12	On-off switch of water jet pump
13.	Fuel Gas Canister
14.	Dipping time control of frying bucket
15.	Main switch on-off of vacuum fryer
16.	Condenser
17.	Air conditioner system
18.	Condensate receiver tank
19.	Temperature regulator of condenser
20.	Fuel tubing
21.	Vapor tubing
22.	Lighter and fuel gas regulator
23.	Frying Vessel

Fig. 1 Schematic diagram of vacuum fryer.

3.3 Frying Time and Moisture Loss

Measurements were carried out for 0, 1, 2, 3, 6, 9, 12 and 15 minutes to study and predict the moisture loss during the rice straw mushroom chips vacuum frying. The prediction of moisture lost was analyzed using the least square design with maximum determination coefficient. The use of Arrhenius models of reaction changes and its logarithmic relationship between vacuum frying time and moisture loss also explored as previously explored by Dincer [10] based on the equilibrium moisture content models, Eq. 1 and Eq. 2.

3.4 Oil Uptake

The vacuum frying time for each treatment was terminated whenever the rice straw mushroom stem chips stopped to bubble, or there was no more emerging bubble observed on the frying oil, which is called bubble end point of the frying. Bubble end point for the rice straw mushroom stem chips vacuum frying was observed from the glass window of the vacuum frying tank. The study was carried out also to study the oil uptake for different thickness of rice straw mushroom stem chips. Study on the effects of the thickness of rice straw mushroom stem chips on oil uptake was carried out using a completely randomized factorial design for three thicknesses of the chips i.e. 2 mm, 4 mm and 6 mm, and five different kind of coating batter containing 0 (only dipping in 2% salt), 5% and 10% of tapioca, and 15% and 30% of dextrin. Each coating batter contains 2% of salt. The samples were naturally oil drained as traditionally practiced for 10 minutes, no whipping nor absorption with paper.

3.5 Physical Properties of Vacuum Fried Chips

3.5.1 Color

The physical property analysis was measured using color analysis instruments (Chroma meter, Minolta CR-200, Japan) in accordance to its manual guidelines. Study on rice straw mushroom chips color was derived based on basic kinetic reaction that the change in color during frying generally followed first order reaction (Eq. 3) and its common integral form [16] (Eq. 4).

$$dC/dt = -kC \qquad (3)$$

$$C = Co\ \exp(-kt) \qquad (4)$$

where, C is the color value at time t, Co is the initial color value before heating and k is the reaction rate constant. Effects of temperature on the rate of reaction usually follow Arrhenius equation (Eq. 5).

$$k = Ao\ \exp(-Ea/RT) \qquad (5)$$

where, k is the reaction rate constant (the color change, min^{-1}) at temperature T (°K), Ao is the frequency factor, Ea is the activation energy ($Cal.mole^{-1}$), R is the gas constant (1.987 $cal.mole^{-1}$ °K) and T is the absolute temperature (°K).

3.5 2 Statistical Analysis

All analyses of vacuum fried products characteristics and properties were carried out in duplicates. The experimental data were analyzed using Analysis of Variance (ANOVA) and continued with Duncan Multiple Range Test (DMRT) to examine the level of the significant difference among experimental mean values (≤ 0.05 and ≤ 0.01) with the assist of Microsoft Office 2007.

4. Results and Discussions

4.1 Proximate Analysis

The moisture content of fresh rice straw mushroom stipe was very high, about 90.8% ± 5.66% which was roughly similar to than other researcher finding [17]. The high moisture contents explained the cause of its perishability and short shelf life. However, average moisture content of the trimmed samples of rice straw mushroom stipe before frying decreased to 84.45% ± 0.34% due to evaporation during the process. The solid content of rice straw mushroom consisted of 70.08% carbohydrate, 20.81% protein, 7.54% ash and very small amounts of 1.58% fat, as shown in Table 1.

Table 1 indicated that the rice straw mushroom chips with presumed average moisture content below

Table 1 Composition of the fresh rice straw mushroom.

Compounds	Average	
	%w.b*)	%d.b**)
Moisture	90.75 ± 5.657	983.45 ± 66.278
Protein	1.92 ± 0.287	20.81 ± 0.963
Fat	0.15 ± 0.034	1.58 ± 0.306
Ash	6.48 ± 0.487	7.54 ± 0.322
Carbohydrate	6.48 ± 0.487	70.08 ± 0.979

*)w.b = wet basis; **)d.b = dry basis, all is of two replicates.

Table 2 Bubble end point of the rice straw mushroom stem chips vacuum frying.

Thickness (mm)	Temp (°C)	Time (minute)*)
2	80	10
2	90	8
2	100	7
4	80	14
4	90	12
4	100	10
6	80	20
6	90	15
6	100	13

*) bubble end point.

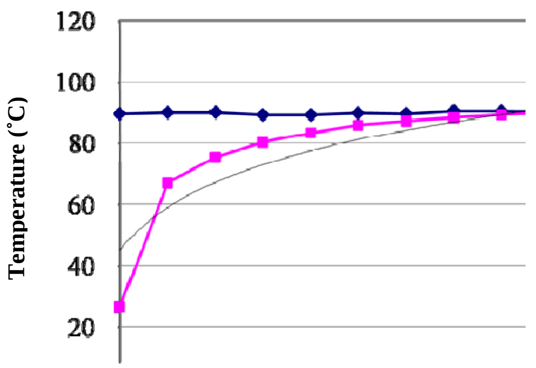


Fig. 2 Temperature profile of the center part of rice straw mushroom chips during vacuum frying.

3% has high potentiality as an excellent food to fulfill amino acids and protein diet foods.

4.2 Bubble End Point and Temperature Profile of the Rice Straw Mushroom Stem Chips Vacuum Frying

Bubble end points of the vacuum fried rice straw mushroom stem chips determined by the disappearance of bubble from the oil are presented in Table 2. It was obvious that the thicker the rice straw mushroom stem chips the longer the bubble end point reached. Likewise, the higher the vacuum frying temperatures the faster the bubble end point achieved.

Temperature profile of the 2 mm thick rice straw stem chips vacuum frying is presented in Fig. 2. The temperature change of the rice straw mushroom chips during vacuum frying basically followed the similar patterns of the deep frying, i.e. consisted of four basic phenomena of initial heating, surface boiling, falling rate temperature increase and bubble end point. The temperature profile explained the reason why during the first minute of vacuum frying the vacuum pressure sharply increased to 11 mmHg although it quickly decreased in the second and the following minutes.

The phenomenon suggested that there was a quick release of moisture vapor from the rice straw mushroom chips during the first minute's initial heating stage of vacuum frying. The sharp vacuum pressure decreased perhaps due to the surface moisture removals during the first minute of vacuum frying. The smaller rate temperature increase during the second and the following minutes of rice straw mushroom chips vacuum frying indicated the stage of falling rate of heat transfer occurred. These phenomena were very likely coincided with the falling rate of moisture removal of the rice straw mushroom stem chips. The temperature profile also indicated that it can be predicted by a dimensionless temperature ratio Eq. 2. The sharp pressure increased in the first minute of vacuum frying was very much in line with the sharp increase in temperature (Fig. 2).

The time and temperature relationship of the vacuum frying process was further predicted by its frying coefficient and the lag factor [11] where the temperature of the center part of the chips was translated into dimensionless temperature distribution ratio of $\phi = (T-T_a)/(T_i-T_a)$, by using Eq. 2 where the $\phi = A_i \exp(b_i t)$ then the pertinent regression analysis resulted in the b_i (the coefficient of frying) and the lag factor A_i. The vacuum frying coefficient is the parameter that showed the capacity of the frying medium that directly correlated with its thermal and water diffusivities. The lag factor or frequency factor indicated the internal and external heat and mass transfer resistance from and into the vacuum fried products.

The regression analysis between time of vacuum frying and the dimensionless ratio of temperature based on the least square analysis showed the lag factor value of the rice straw mushroom stem chips is 0.7, i.e. $\phi = 0.7 \exp(-0.478\ t)$ with strong determinant coefficient of 0.98. These indicated that there was almost no internal or external resistance during the rice straw mushroom stem chips vacuum frying process. The lag factor which is less than one indicated that the heat transfer processes occurred not only by conductive heat transfer. The temperature ratio will be 1.0 when the heat transfer process is conductive where by $T = T_i$.

4.3 Frying Time and Moisture Loss

To study the characteristics of moisture loss during vacuum frying process a coating process with 30% dextrin pre-treatment was carried out. After dipping and draining the coating solution, the weight of rice straw mushroom chips increased up to 36.87% its original weight, and the moisture was around 84.45%. It took 2 (two) minutes generally to lower down the pressure of frying tank to an absolute vacuum pressure of 6 mmHg from atmospheric pressure (76 mmHg). As soon as the rice straw mushroom stem chips were dipped into the frying oil, the vacuum frying tank pressure sharply increased up to 11 mmHg but then returned to the 6 mmHg absolute vacuum pressure. The sharp increase of vacuum frying tank pressure during the first minute of vacuum frying indicated the vigorous evaporation of moisture from the rice straw mushroom stem chips [18, 19] such that the rate of moisture evaporation from the rice straw mushroom stem chips was slightly higher than the capacity of vapor removal from the frying tank. The data [App. 1] convincingly showed that at the first minute of the 80 °C, 90 °C and 100 °C vacuum frying both time and temperature of vacuum frying as well as its interactions were significantly affected the moisture content of the rice straw mushroom chips ($p < 0.01$). Other researchers [20, 21] also reported the same finding that the moisture loss and oil uptake is directly correlated to frying temperature and frying time. Therefore further study was directed to analyze on the effects of 3, 6, 12 and 15 minutes of vacuum frying on the moisture loss during vacuum frying of the rice straw mushroom stem chips. The results showed that significant decrease of moisture content also occurred from the 3 minutes to the 6 minutes vacuum frying at 80 °C (Fig. 3).

The effects of vacuum frying time were significantly decreased the moisture content of rice straw

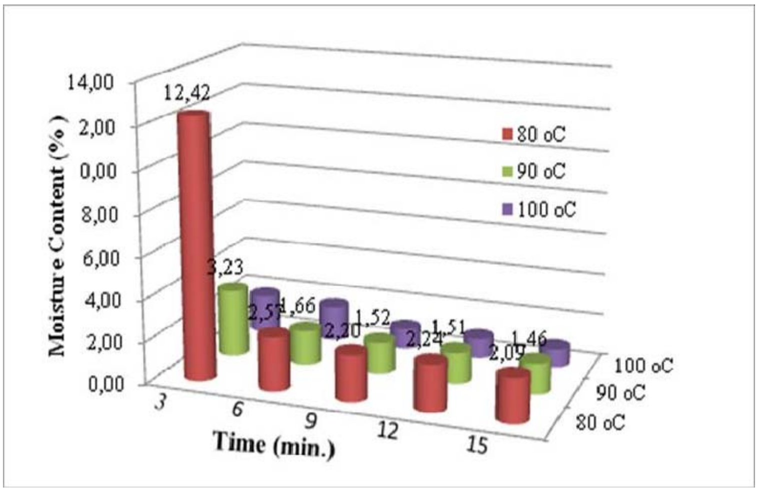


Fig. 3 Effects of time and temperature of frying on the moisture content of rice straw mushroom stem chips.

mushroom chips ($p < 0.01$) especially from the 3 minutes to 6 minutes of vacuum frying. However, the rate of moisture loss among 6 minutes and longer, i.e., 9, 12, and 15 minutes of frying, was not significantly affected ($p > 0.05$). The effects of 3 minutes vacuum frying time at the 90 °C were slightly less ($p < 0.05$) compared to those of the 6, 9, 12 and 15 minutes vacuum frying due to the rate of moisture loss was already lower. While at 100 °C vacuum frying there was no significant different ($p > 0.05$) between the effects of 3 minutes vacuum frying with those of the 6, 12, and 15 minutes of vacuum frying. The DMRT test (Table 3) showed the effects of time and temperature on moisture loss during the rice straw mushroom stem chips vacuum frying. In other words, the rate of moisture removal from the rice straw mushroom stem chips during the 3 minutes vacuum frying was influenced ($p > 0.05$) by the temperature of frying oil and hence by the rate of evaporations.

The DMRT test that after 6 minutes of frying time there were no significant differences ($p > 0.05$) amongst the treatments on the moisture contents of the rice straw mushroom stem chips.

4.4 Effects of Thickness and Oil Uptake

Effects of the rice straw mushroom stem chips thickness and the concentration of the coating batters on the oil uptake of the chips were highly significant ($p < 0.01$). The interactions of both treatments, however, only significantly ($p < 0.05$) affected the oil uptake of the rice straw mushroom stem chips (App. 2a, b, c). There were similar trends of the thickness effects on the rice straw mushroom stem chips oil uptakes for every kind and concentration of the coating batters. The slice thickness of the rice straw mushroom stem chips also significantly affected the oil uptake. Oil uptake of thin slices of rice straw mushroom stipe, during the vacuum frying process was significantly lower than the thicker one, and even lower when the slices were coated with 30% dextrin (Fig. 4). Generally, the thicker the coating batters the lesser the oil uptakes of the rice straw mushroom stem chips. Many research before has proven that hydrocolloids may reduce the oil absorption on the

Table 3 Results of DMRT test on the moisture loss of rice straw mushroom stem chips vacuum frying.

Temperature	Time (Length of vacuum frying)				
80	3	6	9	12	15
90	3	6	9	12	15
100	3	6	9	12	15

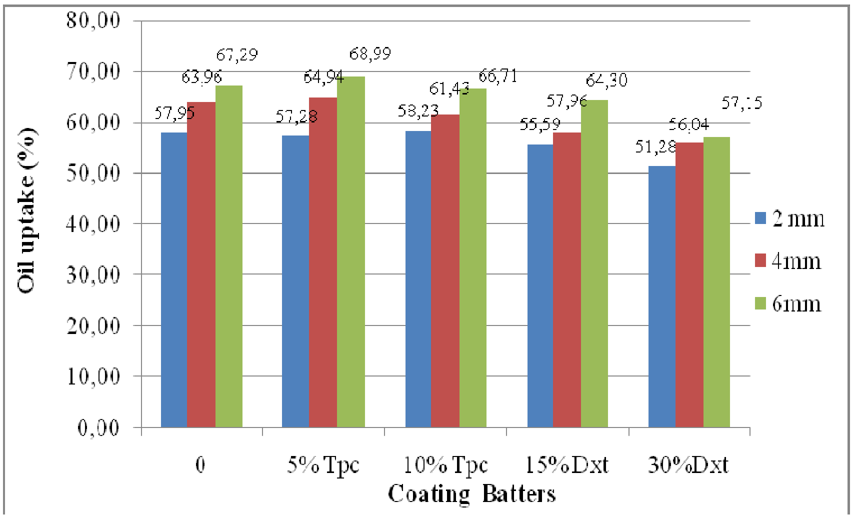


Fig. 4 The oil uptakes of the rice straw mushroom stem chips resulted from various thickness and different coating batter treatments.

final product [22-26]. In addition, coating with 30% batter dextrin resulted in the lowest oil uptake of the chips (average 56.16%). The effects of coating with 30% dextrin batters on the rice straw mushroom stem chips oil uptakes were highly significantly lower ($p < 0.01$) compared with the other coating treatments. 15% dextrin batter coating caused significant effect ($p < 0.05$) on the oil uptake of the chips compared with the other coating batters, except from the 10% tapioca coating batter. Appendix 2c showed the DMRT tests on the effects of thickness on the oil uptake of the rice straw mushroom stem chips. The oil uptake of 2 mm thickness chips was the lowest of all and significantly lower ($p < 0.01$) compared with those of the thicker chips, 4 and 6 mm (Fig. 4).

The oil uptake of the rice straw mushroom stem chips with 4 mm thickness was significantly ($p < 0.05$) lower than those of the 6 mm thick. The thicker the slices, the higher the oil uptake of the vacuum fried rice straw mushroom stem chips. Based on these results it could be suggested that the best rice straw mushroom stem chips was made with 2 mm thick slices and coated with 30% dextrin batter.

4.5 Effects of Vacuum Frying Time and Temperature on Rice Straw Mushroom Stem Chips Color

The colors of rice straw mushroom stem chips were measured one day after storage at room temperature after the vacuum frying processed. The rice straw mushroom stem chips colors were expressed in three dimensions, i.e. Y, x and y values. In general, the colors of rice straw mushroom chips were ranged from dull white to light yellow with the brightness (Y-values), chromaticity x-values and y-values ranging from 15 to 33, 0.36 to 0.38, and 0.36 to 0.383, respectively. The results showed that increased in frying temperature decreased the brightness of the rice straw mushroom stem chips ($p < 0.01$), and its interactions with frying time also decreased ($p < 0.05$) the brightness of the fried chips. While the frying time effects on the brightness of rice straw mushroom stem chips were inconsistent ($p > 0.05$) (Fig. 5).

Temperature of vacuum frying affected the color of rice straw mushroom stem chips at higher temperature all modes of browning reactions are stimulated. These include enzymatic and non-enzymatic reactions and possible caramelization and were in agreement with some previous researches on various cases of high temperature heating [3, 11, 17]. Analysis of Variance showed that the color of rice straw mushroom stem chips fried at 80 °C especially those with 3 minutes frying time is brighter ($p < 0.01$) than those of the 90 °C and 100 °C. Brightness of chips produce by vacuum frying at 90 °C and 100 °C were not different ($p > 0.05$).

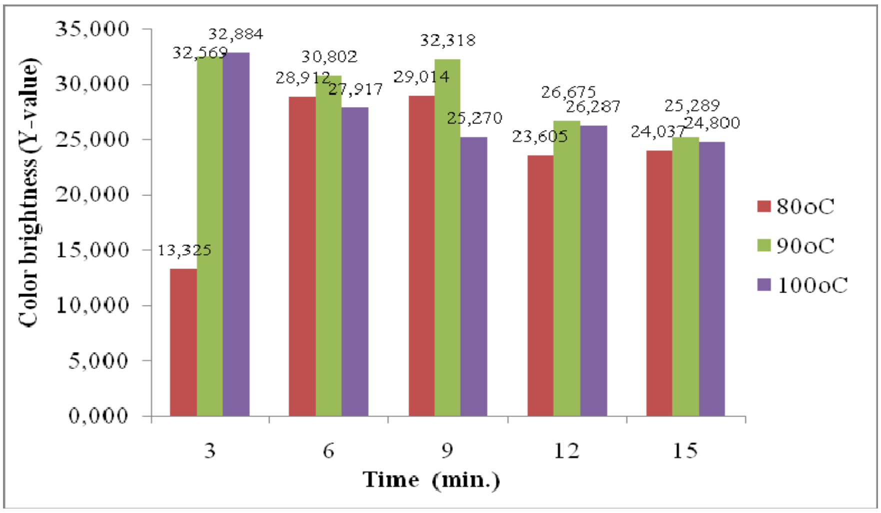


Fig. 5 Effects of temperature and time of frying on the color brightness (Y-value) of the rice straw mushroom stem chips.

Temperature and time of frying of vacuum frying did not significantly affect ($p > 0.05$) the chromaticity (x-values) of the rice straw mushroom stem chips (Fig. 6). Effects of frying time and temperature on the chromaticity x-values were inconsistent, especially with respect to those of the 80 °C frying temperature. Perhaps, this was due to the fact that color of foods also was influenced by the moisture content of the chips. However, the other chromaticity parameter, i.e. y-values were significantly affected ($p < 0.05$). The average chromaticity y-values of the rice straw mushroom stem chips fried at 80 °C is 0.368 which is lower than those of the 90 °C or 100 °C. The y-values of rice straw mushroom chips tended to increase with the increase in vacuum frying temperature (Fig. 7).

4.6 Color Scenario

Basically there was no objectionable color of the rice straw mushroom fried chips and preferable because it looks almost similar to other fried chips. Color profile and size variability of the raw rice straw mushroom and the fried chips were presented in Fig. 8.

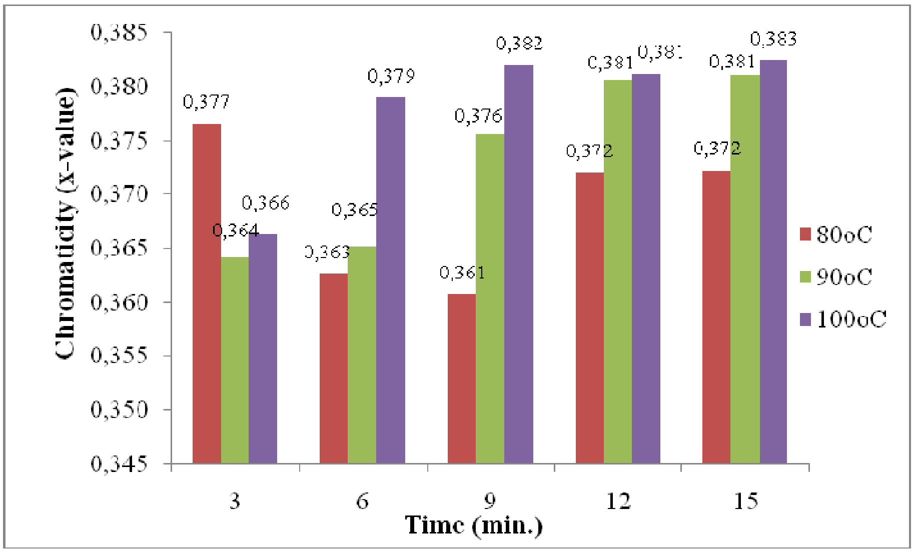


Fig. 6 Effects of temperature and time of frying on the color chromaticity (x-value) of the rice straw mushroom stem chips.

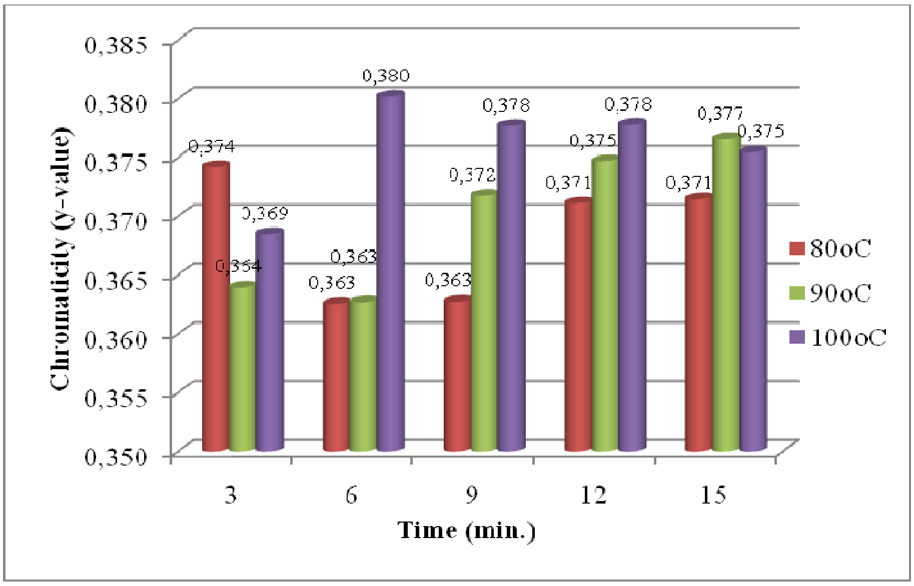
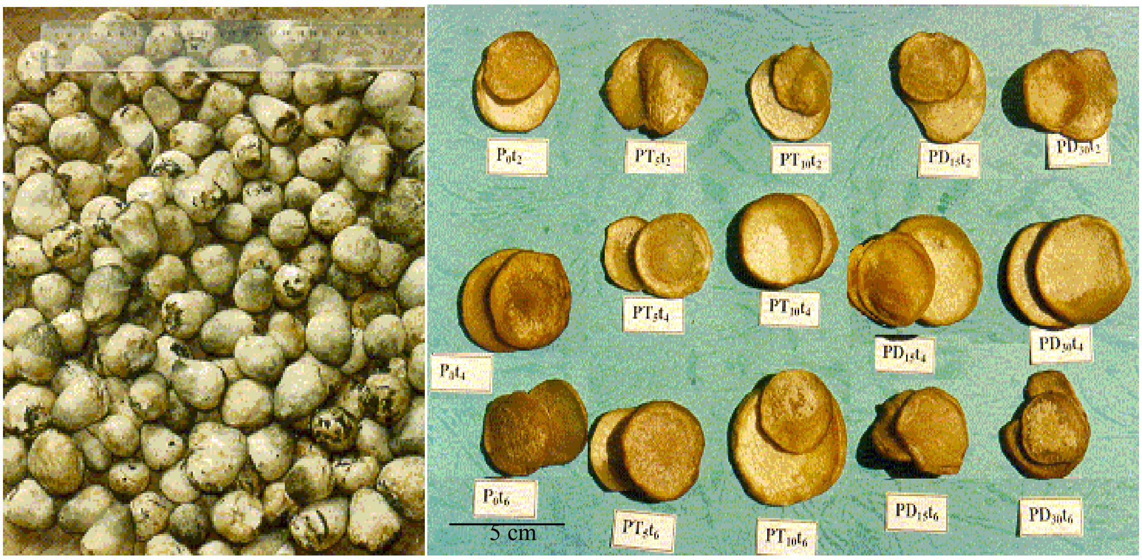


Fig. 7 Effects of temperature and time of vacuum frying on the chromaticity (y-value of the rice straw mushroom stem chips.



Raw (b) Fried chips

Fig. 8 Variability of size and color of (a) the raw and (b) the fried chips of rice straw mushroom. P_0: Control, P_T = coated with tapioca, P_D = Coated with Dextrin, t = thickness.

5. Conclusion

Based on the product quality performance, the optimum conditions for a 2 mm slice thickness chip making is at vacuum frying of 100 °C with 3 minutes vacuum-frying with acceptable color and low oil uptake. Temperature and vacuum frying time and its interactions in general affected the chips color and oil uptake significantly ($p < 0.01$) and correlated with the moisture decrease. The chips moisture loss occurred significantly during the first minutes of vacuum frying. Further moisture declining occurred in 3 minutes of vacuum frying for both 90 °C and 100 °C. While for the 80 °C vacuum frying, the significant decrease of moisture occurred due to the increase of vacuum frying time from 3 to 6 minutes ($p < 0.01$). The chips moisture loss followed generally a two-stage of falling rate pattern during vacuum frying, and each could be well predicted by an exponential equation.

Recommendations

This research is a pioneer research for mushroom stipe chips and a part of Master thesis. Quality performance was only based on other similar product's national standard because there is no Indonesian national standard for mushroom stipe fried chips so far. There are a few of similar fried chips product standards sets for banana chips, cassava chips, tempe chips which prescribed the chip's color must be normal, i.e. light yellow to dark yellow and uniform. The taste of the chips is unique for each pertinent product. The texture shall be crispy, with maximum moisture contents is 7%, maximum fat content is ranging from 30-40 percent. All these chips quality requirements are fulfilled by the fried rice straw mushroom stipe chips resulted in this research except the fat content because the fried products of this research were not centrifuged like in the commercial products. One quality parameter not measured in this research is the chip's texture. Therefore, it is recommended for the future research to focus on the textural characteristics of this mushroom stipe chips evaluation.

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Appendix. 1 Moisture content of the rice straw mushroom stem chips during vacuum frying.

Time (min.)	Temp. 80 °C	Temp. 80 °C	Temp. 90 °C	Temp. 90 °C	Temp. 100 °C	Temp. 100 °C
	I	II	I	II	I	II
0	84.7775	84.1331	84.7775	84.1331	84.7775	84.1331
1	54.0321	54.1358	29.365	29.1644	16.9881	16.7956
2	33.9934	33.5657	16.5463	16.2826	3.7442	3.6565
3	13.6494	11.1889	3.4686	2.9818	2.1165	1.5392
6	2.6941	2.5212	1.8792	1.5200	1.9644	1.3848
9	2.6186	2.0682	1.7985	1.5091	1.1072	0.8936
12	2.4152	1.9051	1.5053	1.4261	1.0559	0.877
15	2.2794	1.7078	1.4921	1.3795	0.9734	0.689

Appendix. 2a Analysis of Variance of chip thickness and coating batter on oil uptake of the vacuum fried rice straw mushroom stem chips.

DESIGN: 2 - way ANOVA, fixed effects; DEPENDENT: 1 variable: Fat content

BETWEEN:

1-Coating (5) : 0 5% Tpc 10% Tpc 15% Dxs 30% Dxs

2-Chips Thickness (3) : 2mm 4mm 6mm

Effect F p-level	Effect	Effect	Error	Error	F	p-level
1	4*	80.1137*	15*	5.108060*	15.68378*	.000031*
2	2*	189.1087*	15*	5.108060*	37.02162*	.000002*
12	8	4.3685	15	5.108060	.85521	.571958

* Significantly different.

Appendix. 2b Duncan's Multiple Range Test of the effects of coating on oil uptake of the vacuum fried rice straw mushroom stem chips.

STAT. Duncan test; Fat content (Mushroom.sta) GENERAL Probabilities for Post Hoc Tests MANOVA MAIN EFFECT: Coating

		{1}	{2}	{3}	{4}	{5}
Coating Batter	Batter	64.55878	65.02870	63.34605	60.63832	56.16592
0	{1}		.723904	.367600	.011510*	.000079*
Tpc5%	{2}	.723904		.239992	.006681*	.000046*
Tpc10%	{3}	.367600	.239992		.055725	.000160*
Dxs15%	{4}	.011510*	.006681*	.055725		.003892*
Dxs30%	{5}	.000079*	.000046*	.000160*	.003892*	

* Significantly different.

Appendix. 2c Duncan's Multiple Range Test of the effects of chip thickness on oil uptake of the vacuum fried rice straw mushroom stem chips.

STAT. Duncan test; K_FAT (Mushroom.sta) GENERAL Probabilities for Post Hoc Tests

MANOVA MAIN EFFECT: TEBAL

Coating	Thickness	{1}	{2}	{3}
		57.52212	62.10541	66.21515
…	2mm {1}		.000536 *	.000089 *
…	4mm {2}	.000536 *		.001145 *
…	6mm {3}	.000089 *	.001145 *	

* Significantly different.