Peculiarities of the use of mushrooms *Agaricus bisporus* and *Pleurotus ostreatus* and effect on the quality and microstructure of chicken batter

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The low energy density and healthier ingredients can replace some or all of the fat in emulsified meat products according to some studies. Meat products with low fat content are the major trends in developing healthier meat products. Attention is drawn that the animal fat is essential for emulsified meat products to enhance the stability, flavor, cooking yield, and texture. As can be noted that compound fat substitutes, such as vegetable protein and carrageenan, vegetable oil and vegetable fibre, cellulose, and water, improved texture better than single fat substitutes. Nevertheless, the character of the emulsified meat product will eventually decrease as the amount of animal fat is reduced. The combination of *Agaricus bisporus* and *Pleurotus ostreatus* mushrooms was employed as a fat substitute to replace the pork-back fat in chicken batters in order to create low-fat chicken products. The microstructure, color, texture, and water holding capability of chicken batters were examined. According to the findings, the combination of *Agaricus bisporus* and *Pleurotus ostreatus* enhanced the cooking yield, texture, water holding capacity, redness, and yellowness of chicken batters, while lowering their brightness. The greatest quality and a compact, uniform, and continuous microstructure were seen in the chicken batters when *Agaricus bisporus* and *Pleurotus ostreatus* at a ratio of 1:1 substituted 40% pork-back fat. To summarize, *Agaricus bisporus* and *Pleurotus ostreatus* are a viable fat alternative in the production of low-fat chicken products.

**Key words:** mushrooms, *Agaricus bisporus*, *Pleurotus ostreatus*, meat, chicken, soybean oil, fat substitute, quality, microstructure.

Особливості застосування грибів *Agaricus bisporus* та *Pleurotus ostreatus* і вплив на якість та мікроструктуру курячого фаршу

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Згідно з деякими дослідженнями, зниження енергетичної цінності і введення ряду сировинних компонентів можуть замінити частину або весь жир у м'ясних продуктах із емульсійної структурою. На сьогодні з'єднали продукти з низьким вмістом жиру з основними течевид-

нями у розробці продукції для здорового харчування. Варто звернути увагу на те, що пташиний жир необхідний для м'ясних продуктів із емульсійною структурою для підвищення стабільності, смаку, ефективності приступування та текстури. Зокрема, такі багатокомпонентні замінники жиру, як рослинний білок і карагена, рослинна олія і рослинна кліткова, єцелоза і вода поліпшують консистенцію продукту, ніж однокомпонентні замінники жиру.

Однак властивості емульсійного м'ясного продукту з часом змінюються у зв'язку зі зниженням кількості пташиного жиру в системі. Використовувались комбінації грибів *Agaricus bisporus* і *Pleurotus ostreatus* для заміни свинячого жиру в курячому фарші та для створення низькожирних курячих продуктів. Було вивчено мікроструктуру, колір, консистенцію та водоімпроникнулину здатність курячого фаршу. Відповідно до результатів дослідження – поживна *Agaricus bisporus* і *Pleurotus ostreatus* підвищують вміст, консистенцію, водоімпроникнулину здатність, колірні характеристики курячого фаршу, однак швидко змінювати його
Introduction

Health issues become increasingly relevant as civilization develops. Fat, as one of the three major nutrients in food, provides the human body with the nutrients it requires; however, excessive fat consumption may result in hypertension, myocardial infarction, and other serious illness, as well as metabolic syndrome and additional illnesses in obese individuals (Zeng et al., 2019; Whisner et al., 2019; Li et al., 2021; Podadera-Herreros et al., 2022). As a result, many kinds of low-calorie, low-fat foods have emerged, rapidly becoming the mainstream of food development in the future. However, as fat plays a large role in the physical characteristics of food – such as appearance, flavor, texture – during food processing, its reduction or removal will significantly (P < 0.05) lower the quality of the meal (Ceron-Guevara et al., 2020). Given this, a key development trend in the manufacturing of low-fat food products has emerged, demonstrating enormous growth potential.

The Agaricus Bisporus (Ab) and Pleurotus ostreatus (Po) mushrooms are low in calories and fat and high in protein, vitamins, dietary fiber, amino acids, and minerals (Çağlarmak, 2009; Qing et al., 2021). Numerous studies have shown that proteins and dietary fibers play a role in the development of the gel system of meat batters. As a result, Ab and Po mushrooms ought to be excellent fat substitutes (Ceron-Guevara et al., 2019, 2020, 2021).

Chicken products are among the most popular emulsified meat products in the world. A typical chicken sausage contains 20–35% fat (Varga-Visi & Toxanbayeva, 2017), which is essential for the water holding capacity, cooking yield, color, and textural features of emulsified meat products (Sorapukdee et al., 2019). In this study, Ab and Po mushrooms were combined for the first time to replace fat in chicken batters, and the effect of this compound on the quality and microstructure of chicken batters was examined to determine the ideal ratio of fat replacement. The findings of this research can serve as a guide for the creation of low-fat chicken products.

Aim of this research

In this study was investigated the effect of mushrooms Agaricus bisporus and Pleurotus ostreatus as fat substitutes in the production of chicken butters. It was determining the cooking yield, water holding capacity, color, texture, microstructure of chicken butters.

Materials and methods

Fresh chicken breast meat, pork-back fat, Agaricus bisporus (Ab) mushroom, Pleurotus ostreatus (Po) mushroom, sugar, white pepper powder, sodium polyphosphate were obtained from supermarket. Ethanol, tert-butanol, glutaraldehyde and trichloromethane were all analytically pure grade.

Preparation of Ab and Po mushrooms powder. Fresh Ab and Po mushrooms were first washed with water to remove the surface dirt and were then cut into slices with a thickness of 3mm and placed in an electrothermal blowing dry oven to dry for 12h at 45°C, so that the moisture content of the mushrooms was below 7%. Then the dried Ab and Po were ground and sieved with 120-mesh sieve to obtain Ab powder and Po powder.

Pre-treatment of chicken and pork-back fat. Excess fat and connective tissue of fresh chicken breasts, as well as the excess connective tissue of pork-back fat, were both taken away before chicken breasts and pork-back fat were ground separately for 1 min using a grinder with a 6 mm perforated plate, and then packed in vacuum bags, respectively. They were then kept at -40°C.

Preparation of chicken batters. The chicken and pork-back fat were taken out and thawed in the refrigerator at 4°C. There are three steps to making meat batters. First, chicken, salt, tripolyphosphate and 1/3 of ice water were mixed in a cutter bowl for 30 s with a pause of 3 min. Second, pork-back fat, Ab and Po mushrooms powder, white pepper powder, sugar and 1/3 of ice water were added and mixed for 2 min, with a pause of 3 min. Third, the remaining 1/3 of ice water was added and mixed for 1 min. The process of preparing the meat batters was kept the same in all experimental treatments. Five treatments were made according to the recipe in Table 1.

Table 1
Recipe for preparing chicken batters

<table>
<thead>
<tr>
<th>Treatment</th>
<th>CK</th>
<th>8:1</th>
<th>4:1</th>
<th>2:1</th>
<th>1:1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chicken/g</td>
<td>120</td>
<td>120</td>
<td>120</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>Pork-back fat/g</td>
<td>40</td>
<td>31</td>
<td>30</td>
<td>28</td>
<td>24</td>
</tr>
<tr>
<td>Ice water/ml</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Ab mushroom/g</td>
<td>0</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Po mushroom/g</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>NaCl/g</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Sodium polyphosphate /g</td>
<td>0.6</td>
<td>0.6</td>
<td>0.6</td>
<td>0.6</td>
<td>0.6</td>
</tr>
<tr>
<td>Sugar/g</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
</tr>
<tr>
<td>White pepper /g</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
</tr>
</tbody>
</table>
Cooking yield of chicken batters. According to Choe et al. (Choe & Kim, 2019) with a slight modification, the chicken batters was placed into a centrifuge tube, which was then centrifuged for 10min at 500 g centrifugal force. Next, the centrifuge tube was placed into a water bath for 30 min at a temperature of 80 °C. After the water bath was completed, the tube was immersed in ice water for 20 min. The cooked chicken batters was taken out and removed the water from the gel surface with filter paper. Then the cooked chicken batters was weighed. The ratio of the weights of the chicken batters after and before cooking was the cooking yield. For each formulation, the measurement was performed three times.

Water holding capacity (WHC) of chicken batters. According to the method of Wang et al. (2021) with a slight modification, 5 g cooked meat batters were wrapped in filter paper and then placed in a centrifuge tube to centrifuge at 8000 r/min for 10 min. After centrifugation, the filter paper was removed. Next, the meat batters were weighed. The ratio of the weight after and before centrifugation was water holding capacity. For each formulation, the measurement was performed three times.

Color of chicken batters. According to the method of Zahari et al. (2020) with a slight modification, cooked meat batters was prepared according to method 2.2.4 and then cut into 25mm in diameter and 20 mm in height to ensure that the cut surface was flat. The color of the meat batters was determined by using a color difference meter at room temperature. The L* value (brightness), a* value (red degree) and b* value (yellow degree) of the meat batters was respectively determined by using the white board after zero adjustment. For each formulation, the measurement was performed five times.

Texture profile analysis (TPA) of chicken batters. According to the method of Li et al. (2020) with a slight modification, the cooked meat batters was cut into a cylinder with a height of 20 mm and a diameter of 25 mm. The springiness, hardness, cohesiveness and chewiness were measured with a texture analyzer. The measurement parameters were as follows: P36R probe, pre-test speed 2.0 mm/s, test speed 2.0 mm/s, post-test speed 5.0 mm/s, compression ratio 50 %, time 5s, trigger type automatic, trigger force 5.0 g. For each formulation, the measurement was performed five times.

Microstructure of chicken batters. According to the method of Nan et al. (2021), the cooked meat batters obtained from CK group and 1:1 group were cut into small cubes with side length of 2mm and soaked overnight with 2.5 % glutaraldehyde (pH 6.8). First, the samples were washed for 3 times with phosphoric acid buffer of 0.1 mol/L pH 6.8 for 15 min each time, and then dehydrated with 50 %, 60 %, 70 %, 80 %, 90 % ethanol for 15 min respectively. Then, the samples were dehydrated for 3 times with anhydrous ethanol for 10 min each time. Then, the samples was defatted with chloroform for 1h, and replaced with anhydrous ethanol: tert-butanol (1:1), and tert-butanol were once for 15min respectively. Finally, after vacuum drying, the surface of the samples were sprayed with gold, and then the microstructure were observed by scanning electron microscopy.

Statistical analysis. Using SPSS 20.0 (IBM) statistical software, the one-way ANOVA and means comparison test (Duncan) were performed to investigate the influence of the various formulations, and the significant threshold was established at 5 %. The data was presented in the form of mean ± standard deviation.

Results and discussion

Effect of Ab and Po mushroom on CY of chicken batters. The CY of chicken batters was the lowest in the control group, and the CY of chicken batters was significantly improved by adding Ab and Po mushroom as fat substitutes (P < 0.05). The best ratio of Ab and Po mushroom was 1:1. This result may be related to the strong water absorption properties of Ab and Po mushroom (Nan et al., 2022).

Table 2
Cooking loss of chicken batters

<table>
<thead>
<tr>
<th>Treatments</th>
<th>CK</th>
<th>8:1</th>
<th>4:1</th>
<th>2:1</th>
<th>1:1</th>
</tr>
</thead>
<tbody>
<tr>
<td>CY /%</td>
<td>94.03 ± 0.75</td>
<td>96.09 ± 1.20b</td>
<td>96.23 ± 1.11b</td>
<td>96.64 ± 1.31b</td>
<td>98.33 ± 1.25a</td>
</tr>
</tbody>
</table>

a–c Means within a line with different letters are significantly different (p < 0.05)

Effect of Ab and Po mushroom on WHC of chicken batters. As can be seen from Table 3, contrary to expectation, WHC in the 8:1, 4:1 and 2:1 treatment groups was not significantly different from CK (P > 0.05). WHC of 1:1 treatment groups was significantly higher than CK (P < 0.05). By comparing with the results of CY value, it is speculated that mushroom powder may exist mainly in the form of physical filling in the meat gel. The ash in mushrooms may be the reason why their WHC does not increase significantly (P > 0.05) (Kurt & Gençcelep, 2018).

Table 3
WHC of chicken batters

<table>
<thead>
<tr>
<th>Treatments</th>
<th>CK</th>
<th>8:1</th>
<th>4:1</th>
<th>2:1</th>
<th>1:1</th>
</tr>
</thead>
<tbody>
<tr>
<td>WHC /%</td>
<td>78.20 ± 0.84b</td>
<td>77.83 ± 0.44b</td>
<td>78.63 ± 0.72b</td>
<td>79.27 ± 0.71b</td>
<td>80.35 ± 0.23a</td>
</tr>
</tbody>
</table>

a–b Means within a line with different letters are significantly different (p < 0.05)
**Effect of *Ab* and *Po* mushroom on Color of chicken batters.** As can be seen from Table 4, the addition of mushroom powder significantly reduced the L* value of meat batters (P < 0.05), but there was no significant difference between the four treatments (P > 0.05), which may be related to Browning during the drying process of mushroom powder. The addition of mushroom powder significantly increased the a* value of meat batters (P < 0.05), and the more *Po* powder was added, the smaller the a* value was. This may be because *Po* mushroom powder has a smaller redness compared with *Ab*. Adding mushroom powder significantly increased the b* value of meat batters (P < 0.05). With the addition of mushroom powder, the b* value of meat batters increased significantly (P < 0.05), which may be related to the higher yellowness of *Po* mushrooms. In short, adding mushroom powder reduced the brightness of meat batters, and increased the redness and yellowness.

**Table 4**  
Color of chicken batters

<table>
<thead>
<tr>
<th>Treatments</th>
<th>L*</th>
<th>a*</th>
<th>b*</th>
</tr>
</thead>
<tbody>
<tr>
<td>CK</td>
<td>85.35 ± 0.30a</td>
<td>0.67 ± 0.40c</td>
<td>10.70 ± 0.36d</td>
</tr>
<tr>
<td>8:1</td>
<td>62.65 ± 0.47b</td>
<td>2.62 ± 0.09a</td>
<td>12.49 ± 0.38c</td>
</tr>
<tr>
<td>4:1</td>
<td>63.08 ± 0.61b</td>
<td>2.36 ± 0.10a</td>
<td>12.65 ± 0.27c</td>
</tr>
<tr>
<td>2:1</td>
<td>62.40 ± 0.74b</td>
<td>1.98 ± 0.06b</td>
<td>13.70 ± 0.28b</td>
</tr>
<tr>
<td>1:1</td>
<td>61.98 ± 0.62b</td>
<td>1.87 ± 0.09b</td>
<td>14.22 ± 0.20a</td>
</tr>
</tbody>
</table>

a–d Means within a column with different letters are significantly different (P < 0.05)

**Effect of *Ab* and *Po* mushroom on TPA of chicken batters.** Table 5 displays the effect of *Ab* and *Po* mushroom quantities on the TPA of chicken batters. *Ab* and *Po* mushrooms altered the TPA of the chicken batter, as shown in Table 5. The hardness and chewiness of the chicken batter considerably enhanced when mushrooms were added (P < 0.05), but there was no distinct difference in chewiness between the 2:1 and 1:1 groups (P > 0.05). When compared to CK, the Springiness of the 1:1 group was substantially higher (P < 0.05). The increase in hardness, chewiness, and springiness of the chicken batter rate of cooking of the dietary fiber in the mushrooms should be connected to the increase in CY (Nan et al., 2022). The ash concentration in *Po* mushrooms was responsible for the considerable drop in cohesiveness in the 2:1 and 1:1 groups compared to CK (P < 0.05). Overall, the 1:1 group had the greatest effect on the TPA of meat batters.

**Table 5**  
TPA of chicken batters

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Firmness (g)</th>
<th>Chewiness (g)</th>
<th>Springiness</th>
<th>Cohesiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>CK</td>
<td>4447.73 ± 120.53d</td>
<td>2765.29 ± 126.37c</td>
<td>0.889 ± 0.002b</td>
<td>0.72 ± 0.01a</td>
</tr>
<tr>
<td>8:1</td>
<td>4572.96 ± 129.25d</td>
<td>2937.00 ± 144.46c</td>
<td>0.890 ± 0.001b</td>
<td>0.73 ± 0.01a</td>
</tr>
<tr>
<td>4:1</td>
<td>5854.15 ± 146.34c</td>
<td>3567.29 ± 123.134b</td>
<td>0.892 ± 0.002b</td>
<td>0.71 ± 0.01a</td>
</tr>
<tr>
<td>2:1</td>
<td>8652.01 ± 127.22b</td>
<td>5028.80 ± 200.24a</td>
<td>0.891 ± 0.003b</td>
<td>0.67 ± 0.01b</td>
</tr>
<tr>
<td>1:1</td>
<td>9170.54 ± 116.21a</td>
<td>5107.45 ± 179.35a</td>
<td>0.900 ± 0.002a</td>
<td>0.66 ± 0.01b</td>
</tr>
</tbody>
</table>

a–d Means within a column with different letters are significantly different (P < 0.05)

**Effect of *Ab* and *Po* mushroom on microstructure of chicken batters.** As indicated in Figure 1, 1:1 group, which were thought to have the best qualitative improvement of all treatment groups was chosen for SEM observation and compared to CK. The observation of the microstructure helped to further clarify the water-binding capacities and textural qualities of meat batters (Wang et al., 2019).

The SEM image mirrored the microstructure of the meat emulsion gel, which might explain WHC of the gel. Smooth gels could bind water effectively, whereas coarse gels were fragile and had a low water retention capacity (Zhuang et al., 2019). The CK had a rough surface and a huge cavity structure. The pore in the microstructure of the microgel was water channel, and big macro pores made it simple for water to escape from the protein network, resulting in enhanced water loss.

The addition of *Ab* and *Po* powder enhanced the gel network density of meat gel, resulting in a compact, homogenous, and continuous gel with fewer pores in the microstructure. Microstructural alterations revealed that adding *Ab* and *Po* powder might increase the water retention of meat batters, fill the protein matrix, and improve the gel strength of meat gel, which were agree with the CY and TPA outcomes in this investigation. *Ab* and *Po* mushrooms possessed a lot of fiber, which might prevent water from escaping by keeping moisture in the protein matrix and decreasing the water channel through the filling process (Cerón-Guevara et al., 2019). As a result, adding *Ab* and *Po* mushrooms to chicken batters improved WHC and microstructure of meat gel.
Conclusion

A compact, homogenous, and continuous gel was produced by partially substituting pork-back fat in chicken batters with Ab and Po mushroom compound. This substitution also raised CY, increased redness and yellowness, and decreased brightness. The cohesiveness of the 2:1 and 1:1 treatments significantly decreased (P < 0.05), whereas WHC, chewiness, hardness, and springiness were increased in the 1:1 treatment. In conclusion, all aspects of chicken batters—aside from cohesiveness—were improved when Ab and Po mushrooms were blended at a ratio of 1:1 to replace 40% of the pork-back fat in the batters.

Prospects for further research. The compound of Ab and Po mushrooms is a promising fat alternative for the production of chicken products.

Information on conflict of interest

There are no any conflicts of interest.

References

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