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EFFECT OF *AGARICUS BISPORUS* ON GEL PROPERTIES AND MICROSTRUCTURE OF CHICKEN BATTERS

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Abstract

Adding animal fat to emulsified meat products can increase the gel properties, juiciness and flavor of the product. *Agaricus bisporus* are rich in protein, polysaccharide, cellulose and flavor substances, which have the effect of absorbing water, gel and can enrich flavor. The purpose of this research was to study the effects of *Agaricus bisporus* on gel properties and microstructure of chicken batters and evaluate its potential as a fat substitute.

This study took chicken breast as raw material and *Agaricus bisporus* as a fat substitute to replace 2, 4, 6, 8, 10, 20, 30, 40, and 50% of animal fat in chicken batters respectively. The cooking loss was calculated by weighing the chicken batters before and after cooking, fat-losing and water-losing were calculated by weighing the exudate before and after drying. pH was measured by pH meter. The color was measured by determining the value of L*, a* and b* of samples using a CR-400 chromatograph. Texture profile were analyzed by TA.XT Plus textural analyzer. Microstructure of chicken batters was observed by environmental scanning electron microscope. The difference and significance of each treatment group were analyzed by IBM SPSS Statistics 20 software.

The results showed that cooking loss and water-losing rate were significantly ($p < 0.05$) reduced when the amount of fat replacement is more than 4% and 10% respectively. Fat-losing rate and pH value were significantly ($p < 0.05$) increased when fat replacement rates were 6 to 30 percent and 4 to 50 percent respectively. The values of L*, a* and b* increased significantly ($p < 0.05$) at all substitution levels because of the color of *Agaricus bisporus*. Hardness and chewiness were significantly ($p < 0.05$) increased when the rates were 20% to 50%. Springiness was significantly ($p < 0.05$) increased when the rates were 8% to 20%.The microstructure of the sample with 20% fat replacement amount was the densest and most uniform compared with the control group.

From the above, appropriate addition of *Agaricus bisporus* was considered to be beneficial to the gel properties and microstructure of chicken batters. In conclusion, *Agaricus bisporus* can be used as a fat substitute to produce low-fat healthy chicken products. The ideal amount of fat replacement is considered to be 20%.

***Key words**: Agaricus bisporus, Gel properties, Microstructure, Chicken batters.*

1. Introduction

Gel-type conditioned meat products are becoming more and more popular with consumers because of their fresh taste, convenient eating and affordable price, which retains the nutrition and flavor of the meat to the utmost extent, and has become a trend in the development of meat products. For example, about 50% of beef is consumed in the form of gelled meat products every year in the United States [1]. Traditional gelatinous meat products are high-fat foods. Animal fats with high saturated fatty acid content are often added in the production. Therefore, excessive intake can cause high blood pressure, hyperlipidemia, cardiovascular disease and cancer [2]. However, animal fat plays an important role in emulsifying stability, cooking yield, texture and flavor of meat products [3]. Therefore, researchers are trying to find a variety of ways to reduce fat in meat products. Reducing the fat content of minced meat directly will affect the texture and flavor of meat products, so fat substitute is a recommended method. At present, there are many reports about fat substitutes. It mainly includes protein (soybean, peanut, pea, wheat, collagen, whey protein, etc.), fat (vegetable oil, emulsifier), and carbohydrate (various colloids, starch, cellulose and other carbohydrate substances) based substitutes [2, and 4 - 6]. Although there are many reports of obtaining healthy foods, some problems related to texture, sensory quality and production cost are also reported [7]. Therefore, it is necessary to develop a new and cheaper animal fat substitute, which can not only maintain or improve the quality of meat products, but also has high nutritional value.

Mushrooms are functional foods, rich in protein, carbohydrates and dietary fiber, but low in fat and energy [8 - 11]. The protein and polysaccharides in mushrooms contribute to the formation of the meat gel structure, improve water retention, and act as an emulsified gel similar to fat. Its unique flavor can also improve the umami and flavor of meat products [12, 13], its rich mineral content [14] can also increase the pH value of meat products, reduce the amount of phosphate [15], and sodium salt added [16] in meat products. Mushrooms are also rich in biologically active ingredients [17], which can improve the antioxidant capacity of the product and extend the shelf life [18]. In short, mushrooms can improve the emulsification stability of meat products, increase the cooking yield, improve texture characteristics and flavor, and play a role similar to fat. Therefore, mushrooms can be used as fat substitutes and have broad market application prospects in the field of meat product processing [19].

Agaricus bisporus is rich in nutrients and is widely cultivated in Europe and North America. Its output accounts for 35 - 45% of the world's total edible fungus production [20, 21], and is very popular in the global food market. There have been some reports on the use of *Agaricus bisporus* as a fat substitute to improve the structure of meat products. For example, *Agaricus bisporus* can be added to beef burgers as natural antioxidants, fat/salt substitutes and flavor enhancers, which is a feasible strategy to reduce the fat content of beef burgers [22]. Adding 2.5% and 5% edible mushroom powder (*Agaricus bisporus* and *Pleurotus ostreatus*) to partially replace the fat and salt in beef patty during cold storage significantly improved the color, elasticity and cohesiveness of beef patty, reduced cooking loss. Meanwhile, the hardness, viscosity and chewiness parameters were similar to those of control samples [23]. After adding 2% of *Agaricus bisporus* powder, the model meat emulsion had better gel properties, and the texture properties of cooked meat emulsion were improved [24]. Although these studies indicate that *Agaricus bisporus* is a promising fat substitute, none of them reported in detail the effect of each addition amount of *Agaricus bisporus* on the quality of meat emulsion, and there are few reports on the application of *Agaricus bisporus* in chicken gel meat products. Therefore, how to better prepare and apply *Agaricus bisporus* to replace fat in chicken gel meat products requires further research.

This study aimed to comprehensively investigate the effect of *Agaricus bisporus* on the gel performance and microstructure of chicken batter when replacing pork back fat with different additions, evaluate its potential as a fat substitute, and provide technical parameters for the application of *Agaricus bisporus* in low-fat meat products.

2. Materials and Methods

2.1 Materials

Fresh *Agaricus Bisporus* mushrooms (AB), chilled chicken breast and pork backfat were purchased from Hualian Supermarket of Xinxiang City. Salt, sodium tripolyphosphate, white pepper, sugar and ice water were all food grade.

2.2 Methods

2.2.1 Preparation of AB powder

AB were washed using tap water, drained the water on the surface, cut into 5 mm thick slices, then put into the oven and dried at 45 ^{0}C for 8 hours until the moisture content was 7%. After natural cooling, the dried AB mushrooms were crushed with a high-speed grinder. Then the mushrooms powder was passed through a sieve of 80 mesh and 120 mesh in sequence. The 120 mesh undersize was obtained, which was packed using a PE plastic bag and placed in a desiccator for subsequent experiments.

2.2.2 Preparation of chicken batters

The chilled chicken breasts meat were minced using a meat grinder (6 mm perforated plate) after removing excess connective tissue and fat. Ground chicken was mixed with salt and tripolyphosphate by a chopper at 1,500 rpm for 60 seconds. After a 3 minutes pause to dissolve myofibril protein, 1/3 ice water was added, the mixture was chopped at 1,500 rpm for 60 seconds to fully dissolve myofibril protein. After a 3 minutes pause, ground chicken was mixed with pork backfat, AB, sugar, ground white pepper and 1/3 ice water depending on the formula (Table 1) by a chopper at

1,500 rpm for 120 s. After another 3 minutes pause, ground chicken was mixed with the remaining 1/3 ice water and chop at 3,000 rpm for 60 seconds. During the chopping process, it was necessary that the center temperature of the mixture was always lower than 10 ^{0}C. The samples without AB powder were used as control. The chicken batters of 10 treatments were manufactured in each batch and 3 independent batches were prepared on the same day. Chicken batters formulations with various fat and AB levels are shown in Table 1.

2.2.3 pH

The pH value was determined carried out as described by Choe *et al.*, [15], with some modification. 10 g of chicken batters were mixed with 100 g of 0.1mol/L potassium chloride solution, the mixture was homogenized (speed, 8,000 rpm) for 1 minute in homogenizer (T25, IKA, Germany). The homogenates were filtered through Whatman No. 4 filter paper (Whatman, Maidstone, England), the pH value of the filtrate was measured with pH meter (Model320, Metler-Toledo Ltd, Essex, UK).

2.2.4 Emulsion stability

According to the method of Fernandez Martin *et al.*, [25] , 25g of chicken batters were loaded into a 50 mL centrifuge tube, and centrifuged at 500 × g for 5 min at 3 ^{0}C to remove air bubbles in the meat batters. The closed centrifuge tubes were heated in a water bath at 80 ^{0}C for 20 min. The tubes were taken out, opened and the tubes were inverted at room temperature for 50 min. to release any exudate onto plates. The exudate was called cooking loss and expressed as % of the initial sample weight. The water loss was expressed as % of the initial sample weight and determined from the dry matter content of total exudate after heating at 105 ^{0}C for 16 h. The fat loss was calculate as the difference between cooking loss and water loss, which ignored any minor protein or salt components. Each treatment group was repeated 4 times.

2.2.5 Textural measurement

40 g of chicken batters was loaded in a 50 mL capped plastic centrifuge tube. And then the batters were heated at 80 ^{0}C for 30 min. in a water bath (the core temperature was 72 ^{0}C) after centrifugation at 500 × g for 5 min. (Sorvall LYNX4000,Thermo Fisher Scientific, Germany).After that, the tubes were cooled to room temperature and then kept overnight at 2 ± 2 ^{0}C until testing. The gels were cut into the cylindrical-shaped (diameter, 6 mm; height, 2 mm) after returning to room temperature. The texture profile analysis was carried out in five replicates for each formulation by the TA-XT plus texture analyzer with a probe P/36R (Stable Micro Systems, UK) at room temperature. The parameters were as follows: pre-test speed, 2mm/s; test speed, 2 mm/s; post-test speed, 5mm/s; trigger type, auto-5 g; time, 5s; and strain, 50%. The hardness, springiness, cohesiveness and chewiness were analyzed.

2.2.6 Color

The color measurement was carried out in five replicates for each formulation using a Minolta chromameter (CR-40, Minolta Camera Co., Japan). The standard white colorimetric plate was L* = 93.56, a* = 0.01, b* = 3.45. A mean was obtained for each L^* (lightness), a^* (redness), and b^* (yellowness) value. Whiteness were calculated as follows Wang L et al. (2019) [7].

$$\text{Whiteness} = 100 - [(100-L^*)^2+a^{*2}+b^{*2}]^{1/2} \qquad (1)$$

2.2.7 Scanning electron microscopy (SEM)

The microstructure was examined by scanning electron microscopy (Quanta 200, FEI CO., USA) using

Table 1. Chicken batters formulations with various fat and AB levels (units: g/100 g)

Raw material/ Ingredients	Fat replacement level (%)									
	0	2	4	6	8	10	20	30	40	50
Meat batter										
Chicken meat	60	60	60	60	60	60	60	60	60	60
Back fat	20	19.6	19.2	18.8	18.4	18	16	14	12	10
AB powder	0	0.4	0.8	1.2	1.6	2	4	6	8	10
Ice water	20	20	20	20	20	20	20	20	20	20
Total	100	100	100	100	100	100	100	100	100	100
Others (% of meat batter)										
Refined salt	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Sodium tripolyphosphate	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Sugar	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
Ground white pepper	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15

the method proposed by Wattanachant *et al.*, [26] with some modification. Cubic samples (3 × 3 × 3 mm^3) obtained from cooked chicken batters was fixed with 2.5% glutaraldehyde in 0.1 M phosphate buffer (pH 6.8) for 24 h at 4 ^{0}C. The fixed samples were washed three times with 0.1 M phosphate buffer (pH 6.8) for 15 min., then dehydrated in a serial solution of 50, 60, 70, 80 and 90% ethanol for 15 min. in each solution, and then dehydrated with anhydrous ethanol(thrice), for 10 min each time. Finally, chloroform was used for degreasing for 1 h, and a mixture of absolute ethanol and tertbutanol (1:1) and tertbutanol were used for replacement for 15 min. respectively. After drying in vacuum, dried samples were sputter-coated with gold after being mounted on a bronze stub. The specimens were observed and photographed in SEM.

2.2.8 Statistical analysis

The effect of the different formulations was analyzed using SPSS 20.0 (IBM) statistical software with a one-way ANOVA and means comparison test (Duncan), and the significance level was 5%. Data is expressed as mean ±S D.

3. Results and Discussion

3.1 pH

As can be seen in Figure 1, with the increase in the amount of fat replacement, the pH value of chicken ground meat significantly increased. This result was consistent with previous studies. Jeehwan Choe and Juri Lee, [15], observed an increase in the pH of pork batter with the addition of winter mushroom powder. This might be due to the buffering effect of proteins in AB powder.

AB contains high levels of basic amino acids such as arginine and histidine at a level of 99.8μmoL and 133.7 μmoL per 100 g sample on a wet weight basis [27], the pH value of AB was 6.5 [24], which was much

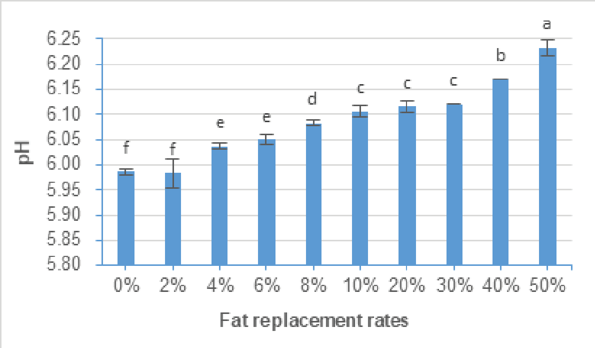

Figure 1. pH value of chicken batters with AB powder as fat substitution

$^{a-f}$Means with different letters are significantly different ($p < 0.05$)

higher than that of blank control (5.99). Higher pH value was more conducive to the formation of meat gels, resulting in a finer gel structure and greater gel strength [28]. This result was inconsistent with the report of Wang, Cheng Li *et al.*, [7],who reported that the replacement of pork backfat with fried *Pleaurotus eryngii* resulted in a reduction in the pH of the sausage, mainly because the pH of fried *P. eryngii* was lower than that of pork backfat.

Based on the above analysis, adding AB powder increased the pH value of chicken batters, which would be conducive to improve the gel structure of meat paste.

3.2 Emulsion stability

The change trend of cooking loss, water loss and fat loss of samples with different fat replacement percentage were different (Table 2). The amount of cooking loss and water loss decreased with the increase of fat replacement amount, fat loss fluctuated with the increase of fat replacement amount, and reached the maximum at 10% replacement (Table 2). The cooking loss and water loss were significantly ($p < 0.05$) different from those in the control group when

Table 2. Emulsion stability of chicken batters with different amounts of fat replacement

Percentage of fat replacem	Emulsion stability		
	Cooking loss (%)	Water loss (%)	Fat loss (%)
0	13.47 ± 0.37a	12.32 ± 0.15a	1.14 ± 0.03d
2	12.83 ± 0.25a	11.77 ± 0.08a	1.06 ± 0.01de
4	12.03 ± 0.75b	10.89 ± 0.03a	1.15 ± 0.01d
6	11.33 ± 0.15b	10.12 ± 0.05a	1.21 ± 0.02c
8	9.87 ± 0.13c	8.33 ± 0.18ab	1.54 ± 0.02bc
10	8.66 ± 0.45d	6.79 ± 0.07bc	1.87 ± 0.01a
20	7.52 ± 0.36e	5.74 ± 0.05cd	1.78 ± 0.02bc
30	5.60 ± 0.18f	4.22 ± 0.02cd	1.38 ± 0.00bc
40	3.47 ± 0.31g	2.38 ± 0.01d	1.08 ± 0.01de
50	1.7 ± 0.30h	0.97 ± 0.01e	0.73 ± 0.01e

Legend: All values are mean ± SD. $^{a-g}$Means within a column with different letters are significantly different ($p < 0.05$).

the fat replacement amounts were more than 2% and 8% respectively, which was closely related to the increase in pH of the chicken batters with different fat replacement amounts. Because the high pH value of chicken batters would have increase the net negative charge of chicken protein, which could have increased its water holding capacity and, subsequently, reduce cooking loss and water loss [29]. In addition, AB contain Hemicellulose, Cellulose and Lignin at a level of 10.10% ,11.39% and 14.68% respectively [24], which have oil absorption and hydration (water uptake, retention, and swelling) properties [30,31]. This result was consistent with the report of Minyi *et al.*, [30], who found that adding dietary fiber significantly reduced cooking loss of meat products. However, the results of fat loss in this study were different. One possible reason for this was that the water holding capacity of AB was stronger than that of oil holding capacity, and a small amount of AB preferentially adsorbed water. With the increase of the amount of AB, the content of free water in the system decreased, subsequently, AB started to absorb a lot of oil, as a result, the loss of fat reduced.

3.3 Texture profile analysis

According to Table 3, the texture parameters of chicken batters increased with the increase of the amount of fat replaced by AB, but the springiness, cohesiveness and chewiness decreased when the added amount was high. When the fat replacement amount was more than 10%, the hardness began to increase significantly. When the amount was 50%, the hardness was the highest, which was 1.37 times of the blank. The springiness of the samples with 8% to 20% fat replacement was significantly higher than that of the control group and other experimental groups. When the fat replacement was 10%, the springiness reached the maximum value of 0.916, but there was no significant difference among the three sample groups. The samples of 40% and 50% group deteriorated in springiness, which is consistent with the research results of Jung Ha *et al.*, [33], whose research reported that adding AB powder to surimi increased the hardness and springiness of surimi. However, the results of this study were inconsistent with those reported by Wong *et al.*, [34], and Chung *et al.*, [35]. Wong *et al.*, [34], reported that adding wet AB to ground beef (80 / 20 fat blend) reduced the hardness of beef. Chung *et al.*, [35], found that adding King Oyster mushroom to cutlefish meat paste reduced the hardness of minced meat. The possible reason was that King Oyster Mushroom with 87.1% moisture content was added in cutlefish meat paste, and high moisture content reduced the hardness of surimi.

When the replacement amount was more than 10%, the chewiness of the sample group was significantly higher than that of the control group. When it was 30%, the chewiness was the best. Nevertheless the difference between 20, 40, and 50% sample groups was not significant. AB powder did not have a strong effect on improving the cohesiveness of chicken batters. When 2% to 8% replaces fat, the cohesiveness of the samples was slightly increased, but only 6% and 8% of the samples were significantly better than the control. When the amount of fat replacement was greater than 8%, the cohesiveness was significantly worse than that of the control. This result was consistent with that reported by Chung *et al.*, [35].

The results of this experiment were contrary to the results of refined dietary fiber from ascidian on the texture of surimi. Hong-Sun *et al.*, [36], reported that fish paste prepared with refined dietary fiber from ascidian, with the increase of fiber content, the springiness decreased and the viscosity increased, which might be caused by the different quality of mushrooms, raw materials and meat.

In the process of making meat, high ionic strength was more conducive to the extraction of myofibrillar protein from meat [37], the structural characteristics of cooked meat products were closely related to the gelation of myofibrillar proteins [38, 39]. AB contain higher Ca, K, Mg, Na and other elements, and the contents were 860, 38,105, 11,099, 234 mg kg^{-1} dm,

Table 3. The textural attributes of cooking chicken batters with different amounts of fat replacement

Percentage of fat replaceme	Firmness (g)	Springiness	Cohesiveness	Chewiness (g)
0	7392.02 ± 462.48d	0.889 ± 0.006bcd	0.71 ± 0.02c	4748.94 ± 310.54c
2	7481.99 ± 293.28d	0.901 ± 0.009abc	0.72 ± 0.01bc	4862.28 ± 637.47c
4	7541.56 ± 259.89d	0.903 ± 0.018abc	0.72 ± 0.01bc	4913.39 ± 107.87c
6	7565.70 ± 650.23d	0.908 ± 0.028ab	0.73 ± 0.01ab	4993.27 ± 372.69c
8	7617.12 ± 368.64d	0.910 ± 0.018a	0.73 ± 0.01a	4929.70 ± 414.02c
10	7730.49 ± 158.19d	0.916 ± 0.019a	0.70 ± 0.00d	4976.29 ± 196.75c
20	8380.79 ± 350.12c	0.911 ± 0.003a	0.69 ± 0.01e	5569.27 ± 302.43b
30	8610.34 ± 287.88bc	0.908 ± 0.002ab	0.67 ± 0.01f	6256.09 ± 209.74a
40	9042.53 ± 312.73b	0.883 ± 0.010cd	0.66 ± 0.01g	5712.12 ± 260.60b
50	10090.66 ± 473.84a	0.874 ± 0.006cd	0.65 ± 0.00g	5725.51 ± 298.78b

Legend: All values are mean ± SD. [a–g] Means within a column with different letters are significantly different ($p < 0.05$).

respectively [14], High metal elements increase the ionic strength of chicken meat, which was conducive to the extraction of soluble protein from chicken meat, thus contributing to the formation of meat paste gel structure. Another reason for the gelation of meat emulsion structure might be related to the presence of dietary fiber and its water-holding behavior [40], the rich dietary fiber of AB was beneficial to the formation of gel structure [24].

High addition of AB was detrimental to springiness, cohesiveness and chewiness, and this inhibitory effect could be attributed to the presence of other components in the mushroom. Such as ash, at higher concentrations, ash will adversely affect the interaction between the hydrophilic groups of the protein and water molecules or the protein-protein interaction [41].

Based on the above analysis, the hardness, springiness and chewiness of chicken batters were significantly improved by replacing 20% fat with AB, although the cohesiveness was decreased. Therefore, 20% replacement was considered the best level.

3.4 Color

The addition of AB powder significantly ($p < 0.05$) changed the L*, a*, b* values and whiteness of chicken batters (Table 4). With the increase of AB powder content, the L* value and whiteness decreased significantly ($p < 0.05$) and lower than control group. Meanwhile, the value of a* and b* increased significantly ($p < 0.05$) and higher than control group. The possible reason was that L* value and whiteness of AB powder were low, nevertheless , a* and b* value were high because of its characteristic yellowish pigmentation, which affected the color of chicken batters. This result was consistent with the report of Jung *et al.*, [33], who found that adding AB powder reduced the L* value and increased the a* value of surimi. Arun *et al.*, [32], reported when adding apple pulp to low-fat chicken nuggets, in each treatment, the color index increased with the increase of apple pulp level. The high redness and yellowness of apple pulp could be the reason for the increase of product chroma index.

Nevertheless , the results of this study were not completely consistent with the results of Ceron-Guevara *et al.*, [23], who reported that the addition of AB powder had a significant ($p < 0.05$) effect on the L* value, but not on the a* and b* values of beef patties. The possible reason was that the beef had higher a* and b* values than chicken.

It could be seen from the above results, the addition of AB powder significantly reduced the whiteness of chicken batters. When the amount of mushroom replacing fat was 50%, the whiteness value was close to that of pork sausage with monascus color [7], but no pigment was added in this experiment. Therefore, AB powder could also be used as a natural food pigment, reducing the amount of other pigments.

3.5 Scanning electron microscopy

The control group and cooked chicken batters with 20% fat replacement, which was considered to have the best qualitative improvement of all treatment groups, were selected for SEM observation, as shown in Figure 2. Observation of these microstructure changes contributed to explain water-binding abilities and the textural properties of the cooked chicken batters.

The scanning electron microscope image reflected the microstructure of the meat emulsion gel, the water holding capacity of the gel could be explained through the scanning electron microscope image. Smooth gels could effectively bind water, while coarse gels were fragile and had poor water holding capacity [42]. The control group (as shown in Figure 2, A, C) without adding AB powder had rough surface and large cavity structure, because the pore in the microstructure of microgel was water channe [43], and large macropores made it easy for water to escape from the protein network, resulting in increased water loss.

Table4. The color of cooking chicken batters with different amounts of fat replacement

Percentage of fat replacement	L*	a*	b*	Whiteness
0%	85.16 ± 0.21a	0.85 ± 0.01h	8.81 ± 0.08h	82.72± 0.22a
2%	81.36 ± 0.28b	1.06 ± 0.05f	10.58 ± 0.06g	78.54± 0.22b
4%	79.80 ± 0.25c	0.74 ± 0.01i	12.12 ± 0.06f	76.43± 0.19c
6%	77.79 ± 0.05d	0.98 ± 0.02g	12.17 ± 0.10ef	74.66± 0.07d
8%	77.69 ± 0.46d	1.18 ± 0.03e	12.33 ± 0.08e	74.49± 0.38d
10%	74.48 ± 0.47e	1.20 ± 0.04e	13.11 ± 0.19d	71.28± 0.34e
20%	68.82 ± 0.11f	1.78 ± 0.08d	17.48 ± 0.17c	64.21± 0.17f
30%	64.90 ± 0.33g	2.36 ± 0.05c	18.17 ± 0.11b	60.41± 0.25g
40%	61.15 ± 0.16h	3.0 ± 0.02b	18.19 ± 0.00b	57.00± 0.15h
50%	60.17 ± 0.32i	3.28 ± 0.03a	18.50 ± 0.09a	55.96± 0.30i

Legend: All values are mean ± SD. a-i Means within a column with different letters are significantly different ($p < 0.05$).

The addition of AB powder increased the gel network density of chicken meat, so that the gel showed a compact, uniform and continuous appearance (as shown in Figure 2, B, D), and the pores in the microstructure decreased. The observation of microstructural changes showed that adding AB powder as a fat substitute could improve the water retention of chicken minced meat, fill the protein matrix and improve the gel strength of chicken batters, which were consistent with the results of water loss and tissue profile in this study. It had been reported that the addition of regenerated cellulose could effectively reduce the pores of water channels and fill the protein matrix, which was easy to intercept the water that was not easy to flow [44]. It was reported that the cellulose content of AB powder was as high as 21.49% [24], so it could be inferred that AB powder prevented water from seeping out through the capture and retention of moisture in the muscle protein matrix and reduced the water channel through the filling action, thereby densified the gel network. Therefore, adding AB could improve the water holding capacity and microstructure of chicken batters.

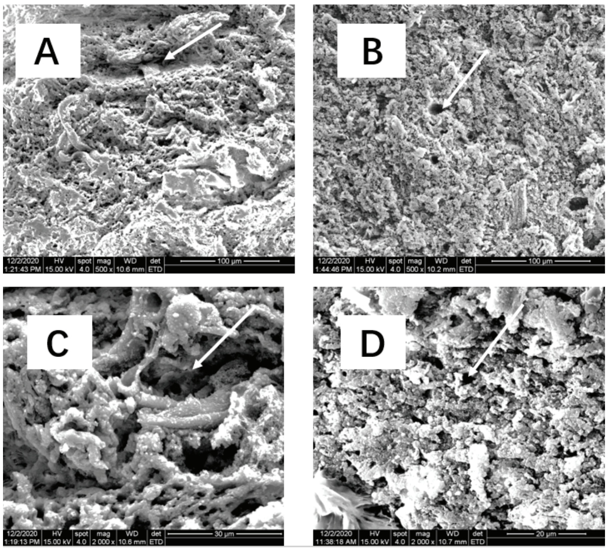

Figure 2. The microstructures of cooked chicken batters observed by scanning electron microscopy
(A) Control without AB, 500 x visual fields;
(B) Replace 20% of the fat with AB, 500 x visual fields ;
(C) Control without AB, 2000 x visual fields;
(D) Replace 20% of the fat with AB, 2000 x visual fields

4. Conclusions

- Replacing the fat with AB will affect the gel properties and microstructure of chicken batters. Under certain substitution amount, adding AB could significantly ($p < 0.05$) increase the pH value, improve the emulsion stability, gel characteristics and microstructure of chicken batters, while the addition of AB will reduce the whiteness of chicken batters.
- In conclusion, AB can be a fat substitute to produce low-fat healthy chicken products. In the scope of this study, combining good change in gel characteristics and microstructure, it is recommended to replace 20% of pork backfat with AB to obtain the best gel quality.

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