Advance Journal of Food Science and Technology 6(8): 973-980, 2014
DOI:10.19026/ajfst.6.142
ISSN: 2042-4868; e-ISSN: 2042-4876

Submitted: March 19, 2014 Accepted: April 15, 2014 Published: August 10, 2014

Research Article

Effect of Edible Gums on the Qualities of Sausage of *Pleurotus eryngii*

[1]Fei Lu, [2]Lei Luo, [1]Xinxue Li and [1]Bo Li
[1]School of Food Science, Henan Institute of Science and Technology, Xinxiang 453003, China
[2]School of Food and Bio-engineering, Henan University of Science and Technology, Luoyang 471023, China

Abstract: *Pleurotus eryngii*, also named king oyster mushroom, is a fast developing mushroom in recent years. This study employed *P. eryngii* as the main material to make sausage-like gel food. The effects of the kinds, addition method and amount and compound of edible gums on the qualities of *P. eryngii* sausage were investigated. The results showed that adding optimal edible gum can improve textural and sensory properties, increase water holding capacity and reduce cooking loss of *P. eryngii* sausage. During nine test edible gums, carageenan exhibited the best influence on sausage's quality on the whole. Carageenan should been added at the powder form and the optimal concentration was 0.6% for mushroom pulp. Compound 0.4% carageenan with 0.2% konjac gum produced better qualities than 0.6% carageenan only. The optimal ingredient for *P. eryngii* sausage was: mushroom pulp 100%, soy protein 15%, corn starch 10%, chicken 18%, carageenan 0.4%, konjac gum 0.2%, sugar 0.7%, salt 1.3%, oil 5% and spices 1.4%. The interior of sausage presented a good network structure and a stable gel system observed by environmental scanning electron microscope. This study shows that sausage preparation is a feasible and potential method for the processing of *P. eryngii*.

Keywords: Carageenan, edible gum, mushroom, *Pleurotus eryngii*, sausage

INTRODUCTION

The oyster mushrooms (*Pleurotus* spp.) are in the third place after the white button and shiitake among the world mushroom production. *Pleurotus eryngii*, also named king oyster mushroom, is considered as the best one of all *Pleurotus* species due to its excellent consistency of cap and stem, culinary qualities and longest shelf life than any other oyster mushroom (Moonmoon *et al*., 2010). In recent years, *P. eryngii* has been commercially cultivated and fast developed in China, Japan and Korea for its excellent flavor and nutrition. It was processed into astronaut food for Shenzhou IX spacecraft in China (Zhang *et al*., 2013). It has been reported that *P. eryngii* has various bioactivities. The endo-biopolymer, containing carbohydrate (77.5%) and protein (21.6%), obtained from submerged culture of *P. eryngii* was found to express antitumor and immunomodulating activities (Jeong *et al*., 2010). Dietary *P. eryngii* significantly improved insulin sensitivity and exerts anti-hyperglycemic and anti-hyperlipidemic effects in db/db mice (Kim *et al*., 2010). The ethanolic extract from *P. eryngii* byproducts showed antioxidative and antimutagenic activities *in vitro* (Kang *et al*., 2012). *P. eryngii* also contains bioactive substances such as hemolysin, phytohemagglutinin, laccase, etc., (Ngai and Ng, 2006; Wang and Ng, 2006).

The mushroom yield of China exceeds 25 million tons, accounting for 70% of total world production. However, the process technology for mushroom falls behind the increase speed of mushroom production. Mushroom is difficult to store for its high moisture content and rich nutrient. As a result, the contradiction between production and marketing is serious during the harvest season. Therefore, exploiting new processing technology is the key for solving the bottleneck of mushroom industry.

Ham sausage is a popular convenience food by consumers. The common sausages use meat as the main material and contain the additives such as nitrite and phosphate. Long term consumption of ham sausage would produce health hazards. Mushroom has crisp texture and rich endo-biopolymers (polysaccharides and proteins), so it is easily processed into gel-like food. There are several reports on replacing part meat with mushroom to make sausage (Sun and Ding, 2006; Li and Li, 2008; Wei *et al*., 2005). However, all these studies used meat as the main material and mushroom just was used as accessory. Recently, our research group has developed the technology of using mushroom as main material to make sausage (Lu *et al*., 2013). Edible gum generally refers to the hydrocolloids used in

Corresponding Author: Bo Li, School of Food Science, Henan Institute of Science and Technology, Hualan Road, Xinxiang City 453003, China

food industry. Most commercially important food gums are polysaccharides which consist of multiple sugars (Doner, 2001). Gums can improve water holding capacity, emulsibility, stability, gelling and thickening properties of foods (Saha and Bhattacharya, 2010; Mudgil *et al*., 2014). The objective of this study was to investigate the effects of edible gums on the textural, sensory and cooking qualities of *P. eryngii* sausage.

MATERIALS AND METHODS

Materials: *P. eryngii* was purchased from local market of Xinxiang City, Henan Province, China. Soybean protein isolate, corn starch, vegetable oil, sugar, salt and spices were food grades. Kappa-Carageenan Gum (CG), sodium Carboxymethyl Cellulose (CMC), Konjac Gum (KG), Xanthan Gum (XG), Locust Bean Gum (LBG), Sodium Alginate (SA), Flaxseed Gum (FG), Tamarind Gum (TG) and Guar Gum (GG) were purchased from Zhengzhou Bota Co. Ltd. Nylon casing was provided by Tianjing Licheng Hongyu Package Co. Ltd.

Preparation of *P. eryngii* sausage: Fresh *P. eryngii* was selected, washed with clean water and cut into slices of 0.5 cm. The slices were put into 100°C boiled water for 3 min, then were taken out and cooled to room temperature. The mushroom slices were crushed and pulped by adding same weight of water. Soybean protein, corn starch, edible gum, sugar, salt, oil and spices were added into the mushroom pulp according to the following proportion: mushroom pulp 100, soy protein 15, corn starch 10, chicken 18, sugar 0.7, salt 1.3, oil 5, spices 1.4 and edible gum 0.6. After intensive mixing, the stuffing was filled into nylon casing and sealed. The sausage was heated at 100°C for 30 min, then cooled to room temperature to obtain the final product.

Effects of edible gums on the qualities of *P. eryngii* sausage:

The effect of kinds of edible gums: Nine edible gum powders (0.6% of mushroom pulp) were mixed with corn starch, respectively and added into mushroom pulp. Through comparing the effects of different gums on sausage qualities, the optimal gum was chosen for the next study.

The effect of adding methods: The optimal edible gum was added into mushroom pulp with two methods. Method one: edible gum powder was mixed with starch and added into pulp. Method two: edible gum was dissolved in ten times of water, then stirring, heating and cooling to form the reversible gel. The gel was added into pulp.

The effect of edible gum concentration: The optimal edible gum was added into mushroom pulp at the concentrations of 0, 0.2, 0.4, 0.6, 0.8 and 1.0%, respectively.

The effect of compound gums: Carageenan (0.4%) was mixed with another gum (0.2%) and added into mushroom pulp.

Textural analysis: *P. eryngii* sausage was cut into cylinder of 2 cm and checked with P 50 probe of TA-XT PLUS textural analyzer (SMS Co., UK). The test parameters were as follows. The velocities before, middle and after test were 2, 1 and 1 mm/sec, respectively. Interval time between two press was 5 sec. Compression ratio was 70%. Data acquisition rate was 200 pps.

Sensory evaluation: Ten trained assessors were invited to taste the sausage samples. The evaluation indexes included appearance, flavor, hardness, elasticity, chewiness, cohesiveness and overall acceptability. The score was from 0 to 7, corresponding to the worst and best evaluation.

Determination of Water Holding Capacity (WHC): WHC was determined according to method of Pérez-Mateos and Montero (2000). The sausage was stripped casing and cut into four same parts along the vertical axis. The sausage parts were weighed and put into centrifuge tube. After centrifuging at 4000 rpm for 50 min, the parts were taken out, absorbed surface water with filter paper and weighed. Every sample was repeated three times. WHC = sample mass after centrifugation/sample mass before centrifugation× 100%.

Determination of Cooking Loss (CL): CL was determined according to the method of Pietrasik (2003). The sausage was cooked at 85°C for 30 min, then stripped the casing and absorbed the surface water with paper. Every sample was repeated three times. CL = (sausage mass before cooking - mass of casing and buckle - sausage mass after cooking) / (sausage mass before cooking-mass of casing and buckle) ×100%.

Environmental Scanning Electron Microscope (ESEM) observation: The central part of *P. eryngii* sausage was cut into slice of 1×1×0.1 cm. The slice was frozen-dried and stuck on sample stage with silver conductive adhesive. The powder on sample surface was blown away and observed with Quanta 200 ESEM (FEI Co., USA).

Statistical analysis: All the experimental results were the mean (±standard deviation) of three parallel measurements. The data was analyzed by statistical software SSPS (ver17.0).

RESULTS AND DISCUSSION

Effect of the kinds of edible gums on the qualities of *P. eryngii* sausage: Nine common-used edible gums were tested to investigate the effects of gum kinds on

Table 1: Effect of the kinds of edible gums on textural properties of *P. eryngii* sausage

Edible gums	Hardness/g	Adhesiveness/gs	Springiness	Cohesiveness	Gumminess/g	Chewiness/g	Resilience
CG	4617±413	202±22	0.80±0.08	0.49±0.05	2023±125	1704±101	0.23±0.02
CMC	3056±1173	223±113	0.75±0.11	0.41±0.02	1282±589	1040±625	0.15±0.03
KG	2612±458	364±118	0.71±0.06	0.38±0.02	979±142	698±107	0.13±0.02
XG	3127±54	278±70	0.76±0.03	0.33±0.01	1034±30	795±8	0.12±0.01
LBG	2311±263	322±57	0.66±0.10	0.32±0.03	774±180	486±178	0.11±0.02
SA	2055±128	384±97	0.65±0.05	0.37±0.03	762±86	495±54	0.13±0.02
FG	2174±73	433±95	0.63±0.01	0.37±0.01	795±37	502±19	0.12±0.01
TG	3538±198	220±42	0.76±0.01	0.48±0.04	1704±51	1288±49	0.20±0.03
GG	2152±175	367±26	0.65±0.08	0.34±0.01	742±76	480±45	0.12±0.01

Table 2: Effect of the kinds of edible gums on sensory qualities of *P. eryngii* sausage

Edible gums	Appearance	Flavor	Hardness	Elasticity	Chewiness	Cohesiveness	Overall acceptability
CG	5.0±1.0	6.0±0.7	5.4±0.9	4.0±0.7	5.4±1.3	5.0±1.2	6.0±1.2
CMC	5.6±0.5	3.4±0.5	3.4±1.1	5.8±0.4	3.0±0.7	3.6±1.1	3.2±1.1
KG	6.8±0.4	3.2±0.4	3.6±1.1	4.6±0.5	3.4±0.9	3.6±0.5	3.0±0.7
XG	3.6±0.5	3.6±1.1	3.8±1.1	4.4±1.1	3.2±1.1	3.6±0.9	2.8±0.8
LBG	5.0±0.7	4.4±0.5	4.4±1.3	4.0±0.7	3.8±1.3	4.2±0.8	3.8±1.1
SA	5.6±0.5	2.8±0.8	3.2±1.6	5.4±0.5	2.8±1.1	3.8±1.5	2.8±1.1
FG	5.8±1.3	1.8±1.1	2.4±1.3	4.4±1.9	2.0±0.7	3.0±1.9	2.2±0.8
TG	5.8±0.4	2.6±0.5	3.2±1.3	5.8±1.3	2.6±0.9	3.2±1.1	2.6±1.1
GG	5.0±1.0	5.2±0.4	5.0±1.4	4.8±0.4	4.2±1.3	4.4±0.9	4.6±0.5

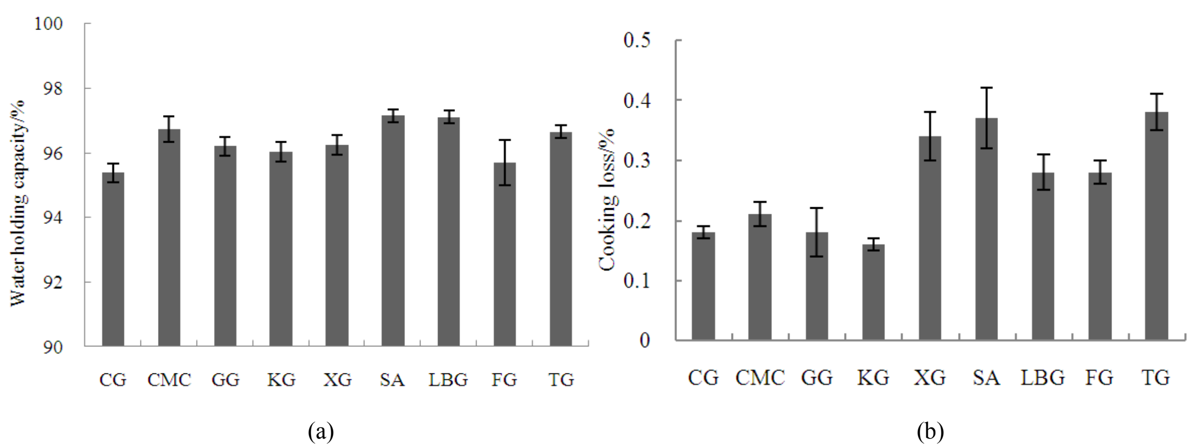


Fig. 1: Effect of the kinds of edible gums on water holding capacity (a) and cooking loss (b) of *P. eryngii* sausage

the qualities of *P. eryngii* sausage. The results were shown in Table 1 and 2 and Fig. 1.

The results showed that gum kinds had significantly influence on the qualities of *P. eryngii* sausage. The hardness, springiness, cohesiveness, gumminess, chewiness and resilience of Carageenan Gum (CG) were higher than other gums and Flaxseed Gum (FG) showed the highest adhesiveness. The following was Tamarind Gum (TG), Xanthan Gum (XG) and Carboxymethyl Cellulose (CMC). CG also showed the best flavor and acceptability on sensory evaluation. The appearance of sausage added with Konjac Gum (KG) was outstanding compared with other gums. The water holding capacity of sausage added with Sodium Alginate (SA) or Locust Bean Gum (LBG) was higher than other gums, but there was no significant difference among nine gums. The cooking loss of sausage added with KG, Guar Gum (GG) or CG was lower than other gums.

From the results it can be seen that different gum exhibited different effect on textural and sensory properties, water holding capacity, cooking loss of *P. eryngii* sausage. In general, sausage added with carageenan showed the best sensory and textural qualities and lower cooking loss than other gums. Carrageenans are a family of linear sulfated polysaccharides that are extracted from red edible seaweeds. All carrageenans are high-molecular-weight polysaccharides made up of repeating galactose units and 3, 6 Anhydrogalactose (3, 6-AG), both sulfated and nonsulfated. The units are joined by alternating alpha 1-3 and beta 1-4 glycosidic linkages. They are widely used in the food industry, for their gelling, thickening and stabilizing properties. Kappa-carageenan is one of the most common used gum in meat processing. Therefore, k-carageenan was chosen as the optimal gum for the further study.

Table 3: Effect of adding methods of carageenan on textural properties of *P. eryngii* sausage

Adding methods	Hardness/g	Adhesiveness/gs	Springiness	Cohesiveness	Gumminess/g	Chewiness/g	Resilience
Powder*	3504±724	264±31	0.83±0.04	0.41±0.04	1429±184	1181±189	0.17±0.02
Gel	2937±25	211±57	0.84±0.03	0.39±0.05	1203±148	1005±67	0.15±0.03

*: Carageenan (0.6%) was added in powder form or reversible gel form

Table 4: Effect of adding methods of carageenan on sensory qualities of *P. eryngii* sausage

Adding methods	Appearance	Flavor	Hardness	Elasticity	Chewiness	Cohesiveness	Overall acceptability
Powder	5.8±0.4	5.2±1.3	5.2±0.8	4.0±0	5.0±1.2	4.8±0.8	5.8±0.4
Gel	4.8±0.4	4.0±0.0	4.0±0.7	6.0±0	3.4±0.9	4.4±1.1	4.2±0.4

Table 5: Effect of carageenan's concentration on textural properties of *P. eryngii* sausage

Concentration/%	Hardness/g	Adhesiveness/gs	Springiness	Cohesiveness	Gumminess/g	Chewiness/g	Resilience
0	4263±478	151±45	0.90±0.00	0.52±0.02	2249±132	1673±553	0.23±0.02
0.2	4325±228	160±22	0.83±0.03	0.58±0.05	2523±356	2096±235	0.28±0.03
0.4	4604±401	113±35	0.86±0.01	0.51±0.07	2512±360	2160±279	0.23±0.04
0.6	4514±562	148±51	0.84±0.02	0.53±0.09	2782±243	2291±218	0.25±0.05
0.8	4007±142	146±48	0.84±0.04	0.47±0.07	1869±217	1567±146	0.21±0.04
1.0	4156±370	157±28	0.87±0.02	0.51±0.03	2102±199	1836±159	0.22±0.02

Table 6: Effect of carageenan's concentration on sensory qualities of *P. eryngii* sausage

Concentration/%	Appearance	Flavor	Hardness	Elasticity	Chewiness	Cohesiveness	Overall acceptability
0	4.6±0.8	4.5±1.1	4.4±1.2	4.8±0.7	5.0±0.8	4.0±0.7	4.3±0.8
0.2	5.3±0.8	4.5±1.0	4.4±0.5	5.3±1.1	4.7±0.7	4.1±1.0	4.6±1.1
0.4	4.7±1.1	5.0±0.9	4.1±1.1	4.4±1.3	4.9±0.9	4.9±0.9	4.8±1.0
0.6	5.9±0.8	4.6±0.8	4.3±0.7	4.9±1.1	4.5±1.0	4.9±1.2	5.0±0.6
0.8	5.1±1.5	4.6±0.8	4.3±0.7	3.9±1.1	4.5±1.1	4.8±1.2	4.4±0.7
1.0	3.8±1.0	3.9±0.8	3.6±0.5	5.4±1.2	3.9±1.2	4.1±1.1	3.9±0.3

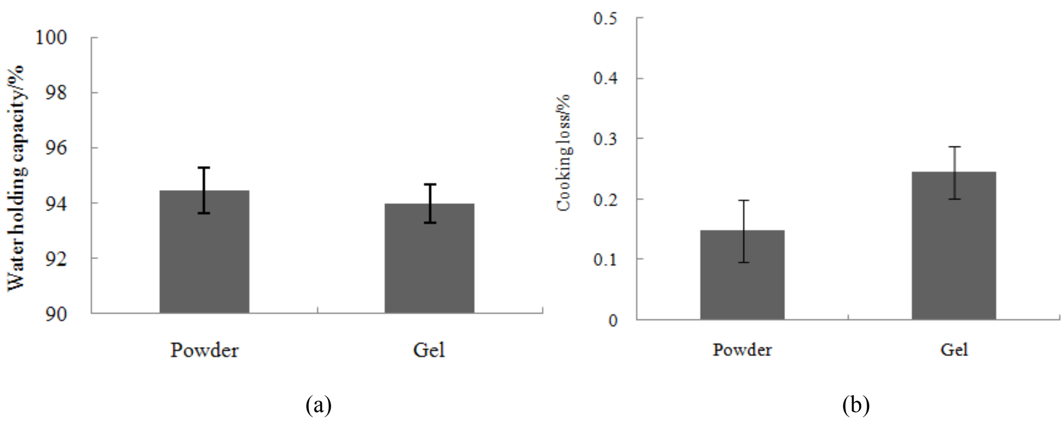
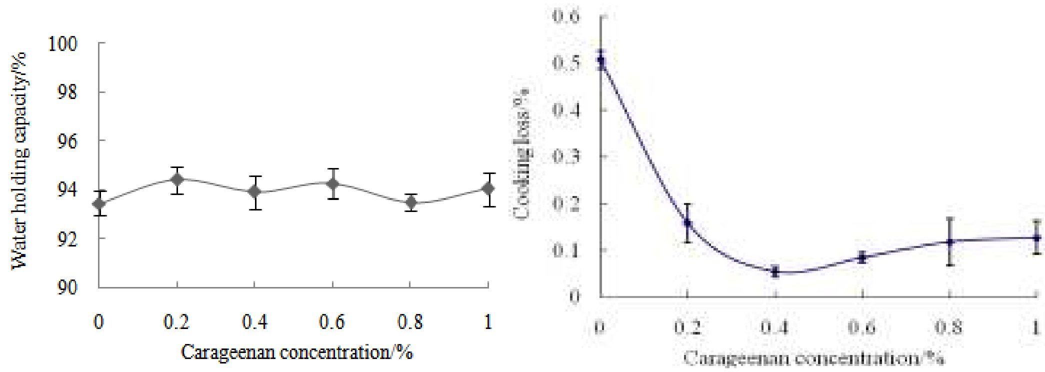


Fig. 2: Effect of adding methods of carageenan on water holding capacity (a) and cooking loss (b) of *P. eryngii* sausage

Effect of adding methods of carageenan on the qualities of *P. eryngii* sausage: Carageenan (0.6%) was added into mushroom pulp with powder form and reversible gel form, respectively. The effect of adding methods on the qualities of *P. eryngii* sausage was shown in Table 3 and 4 and Fig. 2.

The results showed that adding methods of carageenan had some influences on the qualities of *P. eryngii* sausage. Carageenan added in powder form produced better textural and sensory properties than that of reversible gel form. The former also exhibited higher water holding capacity and lower cooking loss. This is because that when carrageen is added in powder form, it can mix with soy protein, corn starch and polysaccharides and proteins in *P. eryngii* intensively. During heating, proteins react with proteins and polysaccharides to form stable and compact network structure. As a result, the sausage quality was improved. When carageenan is added in reversible gel form, the gel will melt and flow out from sausage during heating, leading to the deterioration of sausage quality.

Effect of carageenan's concentration on the qualities of *P. eryngii* sausage: Carageenan was added into mushroom pulp at the concentrations of 0.2, 0.4, 0.6, 0.8 and 1.0%, respectively. The experimental results were shown in Table 5 and 6 and Fig. 3. Table 5 and 6 shows that carageenan's concentration had some effects on textural and sensory qualities of *P. eryngii* sausage. When carageeenan was added at the concentration of 0.6%, the sausage presented better appearance,



(a) (b)

Fig. 3: Effect of carageenan's concentration on water holding capacity (a) and cooking loss (b) of *P. eryngii* sausage

Table 7: Effect of compound gums on textural properties of *P. eryngii* sausage

Compound gums	Hardness/g	Adhesiveness/gs	Springiness	Cohesiveness	Gumminess/g	Chewiness/g	Resilience
CG*	3496±346	161±71	0.82±0.02	0.46±0.03	1539±133	1263±135	0.21±0.02
CG/GG**	3093±496	194±78	0.81±0.03	0.44±0.07	1375±365	1115±337	0.19±0.04
CG/TG	2718±858	183±84	0.84±0.07	0.44±0.07	1263±646	1013±519	0.19±0.05
CG/LBG	3068±889	150±40	0.77±0.03	0.47±0.08	1458±582	1121±457	0.22±0.05
CG/KG	3508±359	213±69	0.84±0.02	0.44±0.05	1524±213	1281±214	0.19±0.02
CG/CMC	2821±460.	196±73	0.80±0.02	0.46±0.02	1294±259	1044±226	0.19±0.01

*: The concentration for CG was 0.6%; **: The compound gums were 0.4% CG mixed with 0.2% another gum

Table 8: Effect of compound gums on sensory qualities of *P. eryngii* sausage

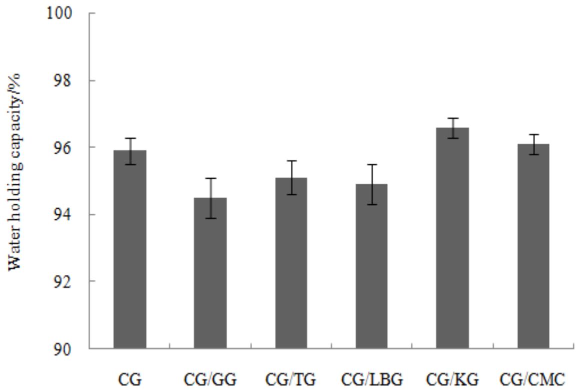
Compound gums	Appearance	Flavor	Hardness	Elasticity	Chewiness	Cohesiveness	Overall acceptability
CG	5.2±0.5	4.8±0.7	4.8±0.8	4.6±0.5	4.6±0.7	5.6±0.8	4.8±0.5
CG/GG	3.2±0.4	3.8±0.8	3.8±1.1	5.6±0.5	4.2±0.4	4.8±0.4	3.6±0.9
CG/TG	4.8±0.8	4.0±1.2	4.8±0.4	4.0±1.0	4.4±1.1	5.4±0.5	4.0±1.2
CG/LBG	3.8±0.8	5.4±0.9	5.2±1.1	4.6±0.9	4.6±1.1	5.6±0.5	4.6±0.5
CG/KG	5.8±0.4	4.6±0.5	4.8±0.8	5.0±1.1	4.6±1.1	5.6±0.5	4.8±0.4
CG/CMC	5.4±0.5	4.8±1.1	4.0±0.7	4.0±0.7	4.4±0.9	5.0±0.7	4.6±1.1

texture and sensory acceptability. Furthermore, sausage showed higher water holding capacity and lower cooking loss at this concentration. It can be seen that adding an optimal amount of carageenan can improve textural characteristics of *P. eryngii* sausage, but excess carageenan would decrease the quality of sausage. Therefore, the optimal concentration for carageenan was 0.6%.

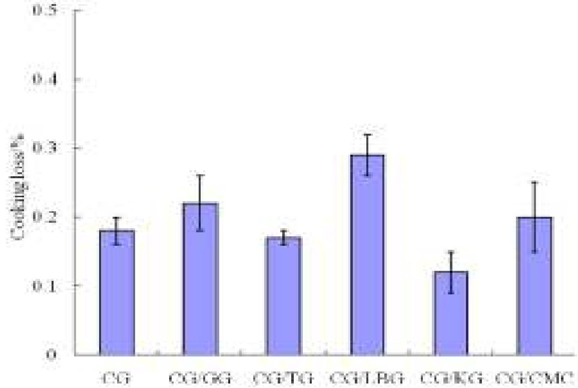
Effect of compound gums on the qualities of *P. eryngii* sausage: Different edible gum has different chemical structure and exhibits specific functions in sausage processing. Using two or more kinds of gums simultaneous probably produce synergistic effect on sausage quality. According to the result of first part, five gums (GG, TG, LBG, KG and CMC) were selected to compound with CG. The effects of compound gums on the qualities of *P. eryngii* sausage were shown in Table 7 and 8 and Fig. 4.

The results showed that 0.4% CG mixed with 0.2% edible gum improved some qualities of *P. eryngii* sausage compared with 0.6% CG, such as appearance, hardness, flavor, adhesiveness, cooking loss and water holding capacity. Among the five gums, KG exhibited attractive result when it compounded with CG. The sausage added with 0.4% CG and 0.2% KG presented higher hardness, adhesiveness, springiness, chewiness, appearance, water holding capacity and lower cooking loss than sausage added with 0.6% CG. The primary component of KG is glucomannan, which is a straight-chain polysaccharide with a small amount of branching. The component sugars are β-(1→4)-linked D-mannose and D-glucose in a ratio of 1.6:1. KG has good gelling and thickening properties and water holding capacity. Therefore, mixing CG with KG can produce better sausage quality than CG only.

Microstructure of *P. eryngii* sausage: To investigate the effect of edible gum on the microstructure of *P. eryngii* sausage, two sausage samples prepared from 100% mushroom pulp, 10% corn starch, 15% soy protein and 18% chicken with or without 0.4% CG/0.2% KG were observed by ESEM. Figure 5a and b showed that *P. eryngii* sausage had a continuous network structure. Polysaccharides and proteins in *P. eryngii*, corn starch and soy protein formed a

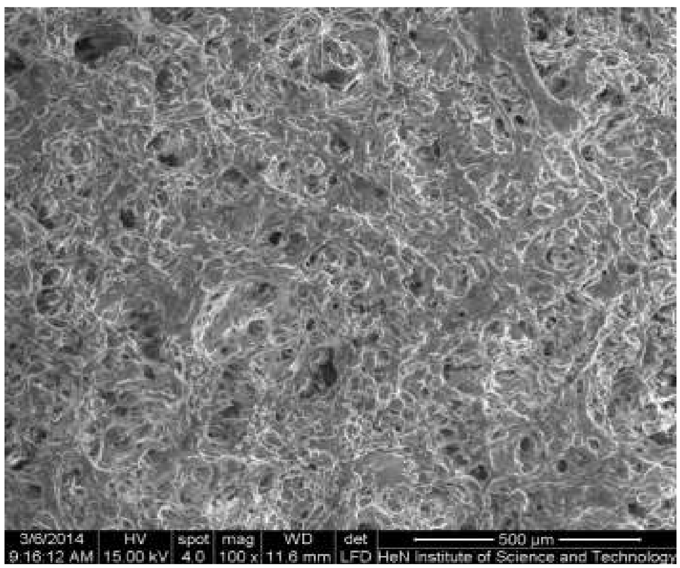


(a)

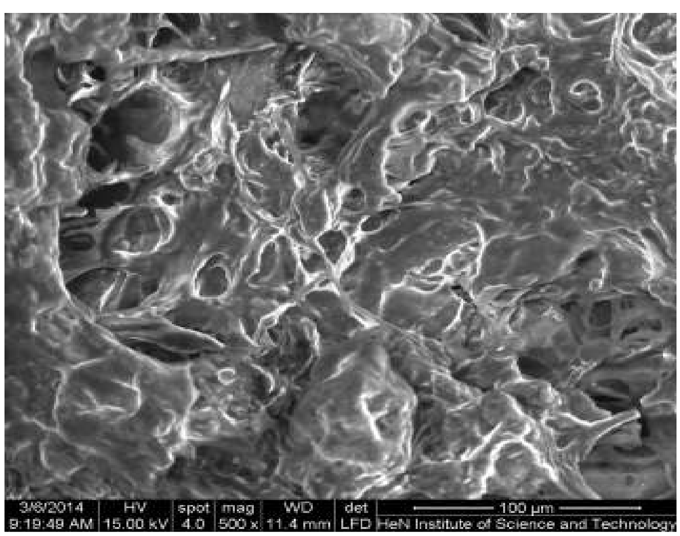


(b)

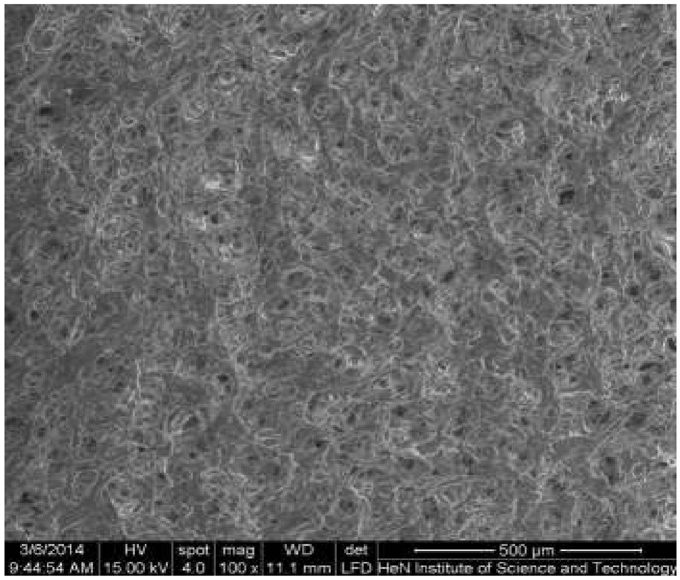
Fig. 4: Effect of compound gums on water holding capacity (a) and cooking loss (b) of *P. eryngii* sausage



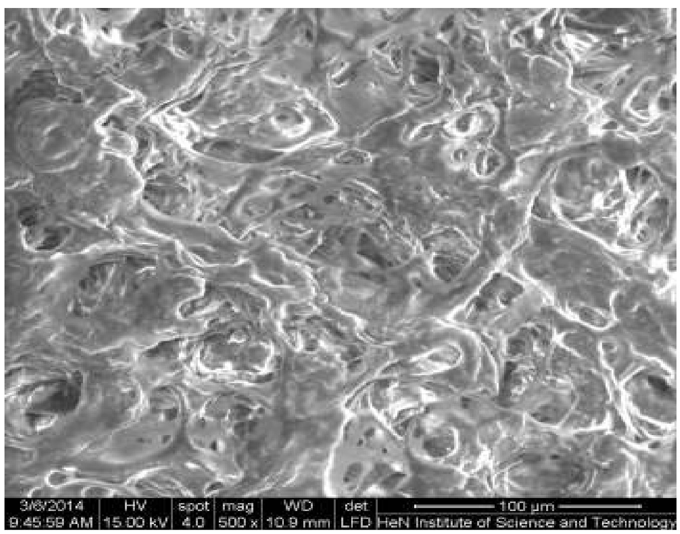
(a)



(b)



(c)



(d)

Fig. 5: ESEM photographs of *P. eryngii* sausage without edible gum (a, b) and added 0.4% CG/0.2% KG (c, d). The magnification rate for a, c was 100 and for b, d was 500

crosslink network and low molecular components were filled in the network. After adding compound gum, the gel network of sausage appeared more compact and continuous. As a result, this sausage exhibited better texture, sensory and water holding properties.

CONCLUSION

This study investigated the effects of kinds, addition method, addition amount and compound of edible gums on the qualities of *P. eryngii* sausage. The results showed that adding certain amount edible gum can improve textural and sensory properties, increase water holding capacity and reduce cooking loss of *P. eryngii* sausage. During nine tested edible gums, carageenan exhibited the best influence on sausage quality on the whole. Carageenan should been added into mushroom pulp in powder form and the optimal concentration was 0.6% for pulp. Compound 0.4% carageenan with 0.2% KG produced better quality and gel network than 0.6% carageenan only. The optimal ingredient for *P. eryngii* sausage was: mushroom pulp 100%, soy protein 15%, corn starch 10%, chicken 18%, carageenan 0.4%, KG 0.2%, sugar 0.7%, salt 1.3%, oil 5% and spices 1.4%. *P. eryngii* sausage has almost same sensory and textural qualities compared with common ham sausage, but the former is more nutrient and safe. This study shows that using *P. eryngii* to prepare sausage is a feasible and potential method for the processing of *P. eryngii*.

ACKNOWLEDGMENT

This study was supported by Excellent Youth Foundation of Henan Province (134100510007), China.

REFERENCES

Doner, L.W., 2001. Determining sugar composition of food gum polysaccharides by HPTLC. Chromatographia, 53(9-10): 579-591.

Jeong, Y.T., S.C. Jeong, Y.A. Gu, R. Islam and C.H. Song, 2010. Antitumor and immunomodulating activities of endo-biopolymers obtained from a submerged culture of *Pleurotus eryngii*. Food Sci. Biotechnol., 19(2): 399-404.

Kang, M.Y., C.W. Rico and S.C. Lee, 2012. *In vitro* antioxidative and antimutagenic activities of oak mushroom (*Lentinus edodes*) and king oyster mushroom (*Pleurotus eryngii*) byproducts. Food Sci. Biotechnol., 21(1): 167-173.

Kim, J.I., M.J. Kang, J. Im, Y.J. Seo, Y.M. Lee, J.H. Song, J.H. Lee and M.E. Kim, 2010. Effect of king oyster mushroom (*Pleurotus eryngii*) on insulin resistance and dyslipidemia in db/db mice. Food Sci. Biotechnol., 19(1): 239-242.

Li, F. and Q. Li, 2008. Research on producing containing *P. ostreatus* sausage. Food Ind., 2: 37-38.

Lu, F., B. Li, S. Li and J. Sun, 2013. Preparation of sausage of *Hypsizygus marmoreus*. J. Henan Ins. Sci. Technol., 41(6): 9-11.

Moonmoon, M., M.N. Uddin, S. Ahmed, N.J. Shelly and M.A. Khan, 2010. Cultivation of different strains of king oyster mushroom (*Pleurotus eryngii*) on saw dust and rice straw in Bangladesh. Saudi J. Biol. Sci., 17(4): 341-345.

Mudgil, D., S. Barak and B.S. Khatkar, 2014. Guar gum: Processing, properties and food applications-A Review. J. Food Sci. Technol., 51(3): 409-418.

Ngai, P.H. and T.B. Ng, 2006. A hemolysin from the mushroom *Pleurotus eryngii*. Appl. Microbiol. Biot., 72(6): 1185-1191.

Pérez-Mateos, M. and P. Montero, 2000. Contribution of hydrocolloids to gelling properties of blue whiting muscle. Eur. Food Res. Technol., 210(6): 383-390.

Pietrasik, Z., 2003. Binding and textural properties of beef gels processed with k-carageenan, egg albumin and microbial transglutaminase. Meat Sci., 63(3): 317-324.

Saha, D. and S. Bhattacharya, 2010. Hydrocolloids as thickening and gelling agents in food: A critical review. J. Food Sci. Technol., 47(6): 587-597.

Sun, M. and M. Ding, 2006. Study on the processing technology of sausage of *Lentinus edodes*. Modern Agri. Sci. Technol., (8): 134-135.

Wang, H.X. and T.B. Ng, 2006. Purification of a laccase from fruiting bodies of the mushroom *Pleurotus eryngii*. Appl. Microbiol. Biot., 69: 521-525.

Wei, G., W. Zhong, C. Yuan *et al*., 2005. Preparation of sausage of enoki mushroom. Meat Ind., 1: 16-18.

Zhang, H., J. Zhang, A. Liu *et al*., 2013. Analysis of nutritional components and bioactive substances of Pleurotus eryngii. Acta Nutrimenta Sinica, 35(3): 307-309.