Food Research 7 (1) : 104 - 112 (February 2023)
Journal homepage: https://www.myfoodresearch.com

FOOD RESEARCH

FULL PAPER

Substitution of Pangasius flesh (*Pangasius hypophthalmus*) by Oyster mushrooms (*Pleurotus ostreatus*) powder in the dry-fermented sausage production

*Minh, N.P.

Institute of Applied Technology, Thu Dau Mot University, Binh Duong Province, Vietnam

Article history:
Received: 25 November 2021
Received in revised form: 28 December 2021
Accepted: 28 February 2022
Available Online: 21 January 2023

Keywords:
Incorporation,
Oyster mushrooms,
Pangasius,
Sausage

DOI:
https://doi.org/10.26656/fr.2017.7(1).950

Abstract

Overconsumption of processed muscle products was associated with health problems. Consumers preferred healthier food by limiting fauna ingredients and increasing floral sources in the foodstuffs. Oyster mushrooms (*Pleurotus ostreatus*) could be obtained in high quantity and good quality from the utilization of agro-industrial waste in a short time in a saving area. Oyster mushrooms were well known as one kind of healthy vegetable due to their low cholesterol content but high proximate composition. The purpose of this research was to evaluate the possibility of partial replacement of Pangasius (*Pangasius hypophthalmus*) scrapped muscle by oyster mushrooms powder (0-35%) to the physicochemical attributes of the dry-fermented sausage. Dried powder oyster mushrooms were mixed with different ingredients like modified starch, garlic, onion, black pepper, cinnamon, clove, ginger, coriander, sodium chloride, sodium glutamate, sugar, liquor, and then stuffed in cellulose casing (30 mm diameter, 150 mm length), and formed sausage. The raw sausage was then dry-fermented at 55^{o}C for 72±2 hrs. The dry-fermented sausage was sealed in a vacuum bag and kept for 6 months at room condition. In 2 month-interval, sausages were sampled to evaluate hydrogen accommodating ability, cooking loss, thiobarbituric acid reactive substances (TBARS) value, and overall acceptance. Results showed that the 25% oyster mushrooms incorporation into scrapped muscle Pangasius fish induced the lowest cooking loss and thiobarbituric acid reactive substances (TBARS) value while the highest hydrogen accommodating ability and sensory score during 6 months of vacuum storage. Oyster mushrooms revealed a promising alternative to replace meat in sausage production.

1. Introduction

Sausage products were prepared from minced meat either fish (Minh and Nga, 2018; Minh, 2021), shrimp (Minh *et al.,* 2019), pork (Marina *et al.,* 2021), beef (Babatunde *et al.,* 2021), chicken (Saricoban *et al.,* 2006), sheep (Alfredo *et al.*, 2020), goat (Rai *et al.,* 2008), lamb (Svanberg, 2015), buffalo (Rai *et al.,* 2009), camel (Abd-ElGhany *et al.,* 2020), horse (Stajic *et al.,* 2012), mutton (Zeng *et al.,* 2016); formulated with food additives and seasoning ingredients; stuffed into proper cylindrical casings, and ageing-dried (Raju *et al.,* 2003). Abundant animal/fish fat in sausage caused a high risk of high cholesterol and obesity (Drewnowski, 2018). Heavy consuming habits of animal/fish sources induced the over raising and slaughtering of animal/fish to satisfy the consumer demands that are directly affected by the green -house effect from gas emission, land- exhausted exploitation, water pollution, and animal/fish mistreatment (Poore and Nemecek, 2018). Dietary behaviours in cuisine would create a foundation for a healthy body with minor hazards of lifestyle ailments. It's necessary to replace animal/fish fat fully or partially with healthy sources rich in protein, carbohydrates, fibre while retaining the most technical characteristics of the true product (Aslinah *et al.,* 2018; Carvalho *et al.,* 2019; Choe and Kim, 2019).

Oyster mushrooms (*Pleurotus ostreatus*) could be manufactured in high biomass from recycling agro-industrial waste per small unit space and short duration of cultivation (Kakon *et al.,* 2012). Oyster mushrooms was rich in protein, fibre, vitamins, minerals, and phenolic constituents but low fat, free cholesterol (Lu *et al.,* 2020). Numerous bio-therapeutic benefits of oyster mushrooms-like antihypertensive, antitumor, anti-

*Corresponding author.
Email: *nguyenphuocminh@tdmu.edu.vn*

eISSN: 2550-2166
Published by Rynnye Lyan Resources

angiogenesis, and anticancer were mentioned (Synyttsya *et al.,* 2008). Mushroom could be utilized to partially incorporate into meat products due to its pleasant savoury taste accounted by amino acids and 50 - nucleotides (Chye *et al.,* 2008; Zhang *et al.,* 2013; Moon and Lo, 2014; Mehta *et al.,* 2015). The mushroom was demonstrated to be a promising candidate to replace fat in different meat products such as salted cooked beef (Alnoumani *et al.,* 2017), meatballs (Ramle *et al.,* 2021), chicken patties (Wan Rosli *et al.,* 2011), chicken sausage (Jo *et al.,* 2018), pork sausage (Wang *et al.,* 2019), goat meat nuggets (Banerjee *et al.,* 2020), yellowtail meat (Bao *et al.,* 2009), kuruma shrimp (Encarnacion *et al.,* 2010), sutchi catfish patties (Nayak *et al.,* 2015). The mushroom extract was effective to maintain the colour and shelf life of tuna flesh (Stephen, 2009). There were no studies that verified the possibility of mushrooms incorporated into Pangasius fish sausage. The purpose of the current study verified the possibility of different replacement ratios (0-35%) of Pangasius muscle by oyster mushrooms while ensuring the physicochemical and sensorial attributes of the true Pangasius sausage in 6 -month handling.

2. Materials and methods

2.1 Materials

Pangasius scrapped meat was utilized from Pangasius processing factories in Can Tho province, Vietnam. Pangasius fishes were cultured following the Global GAP standard to ensure food hygiene, safety, and traceability. After being collected, they were preserved by flake ice at 0-4^{o}C in the chill crate and transferred to the laboratory quickly. Oyster mushrooms was collected from a farm in Soc Trang province, Vietnam. Oyster mushrooms was cultivated following Viet GAP standard to ensure food hygiene, safety, and traceability. After being harvested, the oyster mushrooms were preserved in a dry-cooled container and quickly moved to the laboratory for experiments. Food additives and ingredients used for sausage production including modified starch, garlic, onion, black pepper, cinnamon, clove, ginger, coriander, sodium chloride, sodium glutamate, sugar, liquor were all food-grade that was purchased from the grocery store. Chemical reagents Thiobarbituric acid (99% purity), malondialdehyde tetrabutylammonium salt (97% purity), glacial acetic acid (99% purity) was all analytical grade that was bought from Sigma-Aldrich (Steinheim, Germany).

2.2 Sample preparation

Oyster mushrooms was convective-dried at 50^{o}C for 24 hrs, then it was finely ground into powder the by grinder. The formula of ingredients in the preparation of 1,000 g of Pangasius sausage was elaborated as in Table 1. All ingredients in the mixture were mixed thoroughly in the cutter, stuffed in cellulose casing (30 mm diameter, 150 mm length), and formed sausage. The fresh fish sausage was then dry fermented at 55^{o}C for 72±2 hrs. The dry-fermented sausage was packed in a vacuum bag and stored for 6 months at ambient temperature. In 2 month-interval, samples were taken to examine hydrogen accommodating ability, cooking loss, thiobarbituric acid reactive substances (TBARS) value, and overall acceptance.

2.3 Physicochemical analysis

2.3.1 Hydrogen accommodating ability

Hydrogen accommodating ability (%) was estimated

Table 1. Ingredients (g) in preparation of 1,000 g of Pangasius sausage

Ingredients	Percentage (%) replacement of scrapped muscle fish by oyster mushrooms powder							
	0	5	10	15	20	25	30	35
Scrapped muscle fish (g)	800	760	720	680	640	600	560	520
Mushroom powder (g)	0	40	80	120	160	200	240	280
Modified starch (g)	60	60	60	60	60	60	60	60
Allium sativum (g)	4	4	4	4	4	4	4	4
Allium ascalonicum (g)	4	4	4	4	4	4	4	4
Piper nigrum (g)	3	3	3	3	3	3	3	3
Cinnamon (g)	2	2	2	2	2	2	2	2
Glove (g)	2	2	2	2	2	2	2	2
Ginger (g)	2	2	2	2	2	2	2	2
Corriander (g)	2	2	2	2	2	2	2	2
Sodium chloride (g)	20	20	20	20	20	20	20	20
Sodium glutamate (g)	5	5	5	5	5	5	5	5
Sugar (g)	10	10	10	10	10	10	10	10
Liquor (mL)	25	25	25	25	25	25	25	25
Ice (g)	60	60	60	60	60	60	60	60

https://doi.org/10.26656/fr.2017.7(1).950

following the procedure described by Dosh *et al.* (2016). The sausage (5 g) was milled, and well blended with 10 g of distilled water by a stomacher (Stomacher 400 Circulator, Seward, UK), then centrifuged (Sigma 3-30KHS, Sigma Laborzentrifugen GmbH, Germany) at 4,000 rpm for 3 mins. After heating at 80°C for 5 mins, the upper layer was decanted, and samples were weighed. The samples were then kept at 4±0.5°C for 24±2 hrs and centrifuged at 5000 rpm for 3 mins at ambient conditions (Sigma 3-30KHS, Sigma Laborzentrifugen GmbH, Germany). The outcome upper layer was separated using Whatman filter paper No. 3 and samples were weighed. Hydrogen accommodating ability (%) was identified with the respected formula: HAA (%) = $[(M_2 - M)/ (M_1 - M)] \times 100\%$, where M is the mass of the sausage (g), M_1 is the mass of the sausage after heating and decanting the upper layer (g), and M_2 is the mass of the sausage after centrifuging and separation of outcome upper layer (g).

2.3.2 Cooking loss

Cooking loss (%) was estimated by weighing the sausage prior to heating and after heating (at 98±0.5°C for 10 mins) and calculated using the following formula (Wangteui *et al.,* 2020).

$$\text{Cooking loss (\%)} = [(W_1 - W_2) * 100\% / W_1]$$

Where W_1: weight of uncooked sausage (g), and W_2: weight of cooked sausage (g).

2.3.3 Thiobarbituric acid reactive substances

Thiobarbituric acid reactive substances or TBARS (mg malonaldehyde/kg) was determined following the 2-thiobarbituric acid spectrophotometric method (Anna *et al.,* 2017). An amount of 58 mg of thiobarbituric acid was dispended in 100 mL of glacial acetic acid to obtain 4.0 mM of thiobarbituric acid (TBA). Amount of 31.35 mg of malondialdehyde tetrabutylammonium salt was dispended in 100 mL of glacial acetic acid to obtain 1.0 mM of malondialdehyde tetrabutylammonium (MDA) solution. From the original mixture, a set of concentrations from 0.1 to 0.8 mM were prepared and ready to build the calibration curve. An amount of 1 g of fine sample was inserted into 25 mL test tube and 5 mL of pure glacial acetic acid. The sample was mixed for 30 mins, filtered by Whatman filter paper No. 3. The filtrate was centrifuged at 3,500 rpm for 3 mins and ready for analysis. An aliquot of 1 mL of the standard MDA solution was dispensed into a 10 mL test tube and dissolved with TBA (1 mL). The composite was burned at 100°C for 45 mins. The test tubes were left to cool at ambient conditions and absorbance was recorded at 532 nm using a UV-visible spectrophotometer (Shimadzu, UV-1800). Acetic acid was used as a blank sample.

2.3.4 Overall acceptance

Overall acceptance was determined by a team of eleven specialists utilizing a 9-point Hedonic scale. Panellists of eleven assessors (age 30-40 years old) were previously trained (90 hours) before the official evaluation. During the training, panellists were individually evaluated to determine the overall panel mean and to ensure that all panellists were able to scale the properties of interest.

2.4 Statistical analysis

The demonstrations were performed in triplicate with various sets of patterns. The results were expressed as average ± standard deviation. Statistical analysis was handled by the Statgraphics Centurion version XVI. The average number ($\bar{x}$) and standard deviation ($2s$) of a group of records were received from the parsing of accidental patterns evaluating the population statistics. A percentage of 95% of outcomes would be anticipated to situate in the scope $\bar{x} \pm 2s$. The inferior and superior limits of this extent were elaborated at the 95% confidence limits of the outcomes. The variances between the regarded patterns were summarized utilizing a one-route parsing of variance (ANOVA). A substantial record is established at a 95% confidence dimension ($p \leq 0.05$). If substantial distinctions were noticed, then a post hoc summary was handled implementing Duncan's multiple range analysis.

3. Results and discussion

3.1 Hydrogen accommodating ability of Pangasius sausage partially replaced by oyster mushrooms during storage

The effect of oyster mushroom incorporation (0-35%) on hydrogen accommodating ability (HAA) of the formulated sausage in 6 months of preservation was presented in Table 2. There was a decreasing trend of hydrogen accommodating ability by the time of keeping. The hydrogen accommodating ability of the formulated sausage increased by the oyster mushrooms ratio (0-25%) and decreased afterwards. The amount of 25% oyster mushroom replacement induced to the highest hydrogen accommodating ability with a gradual reduction (85.71±1.425 down to 70.34±1.32%) during 6-month storage. Meanwhile, the control sample showed the lowest hydrogen accommodating ability with a rapid decrease (40.27±1.08% down to 32.02±1.17%) during storage. A loss of texture in sausage caused a decrease in sausage's hydrogen accommodating ability by adding oyster mushrooms above 25% and during storage.

Chicken sausage incorporated with oyster mushrooms strongly affected hydrogen accommodating

https://doi.org/10.26656/fr.2017.7(1).950

Table 2. Hydrogen accommodating ability (%) of Pangasius sausage partially replaced by Oyster mushrooms (%) during storage (months)

Oyster mushrooms (%)	Storage (months)			
	0	2	4	6
0	40.27 ± 1.08^{eA}	38.85 ± 1.23^{eAB}	36.41 ± 1.05^{eB}	32.02 ± 1.17^{eC}
5	47.90 ± 1.32^{deA}	43.29 ± 1.13^{deAB}	39.70 ± 1.22^{deB}	33.59 ± 1.26^{deC}
10	51.63 ± 1.25^{dA}	48.04 ± 1.21^{dAB}	45.37 ± 1.19^{dB}	37.64 ± 1.35^{dC}
15	62.84 ± 1.40^{cA}	57.38 ± 1.32^{cAB}	53.26 ± 1.26^{cB}	47.35 ± 1.28^{cC}
20	75.15 ± 1.36^{bA}	72.86 ± 1.19^{bAB}	69.14 ± 1.07^{bB}	60.08 ± 1.15^{bC}
25	85.71 ± 1.42^{aA}	82.90 ± 1.24^{aAB}	78.53 ± 1.25^{aB}	70.34 ± 1.32^{aC}
30	67.40 ± 1.25^{bcA}	62.36 ± 1.40^{bcAB}	59.71 ± 1.08^{bcB}	51.37 ± 1.06^{bcC}
35	56.79 ± 1.28^{cdA}	52.58 ± 1.31^{cdAB}	49.42 ± 1.20^{cdB}	41.05 ± 1.18^{cdC}

Values are presented as mean±SD of triplicates. Values with different lowercase superscript within the same column and values with different uppercase superscript within the same row are significantly different (P<0.05).

ability (Syuhairah *et al.,* 2016). Pork sausage supplemented with winter mushroom powder showed an increment of HAA (Choe *et al.,* 2018). Hydrogen accommodating ability in meat sausage was increased by 15% mushroom incorporation (Al-Dalain, 2018). The 20% oyster mushrooms flour was incorporated with 77% sea cork fish to formulate analogue sausage (Emy and Kamsiah, 2018). Fresh marine catfish sausage incorporated with 10% of smoked pork back fat showed a high-hydrogen accommodating ability (Vieira *et al.,* 2019). Goat meat nuggets revealed high HAA by the addition of enoki mushroom (Banerjee *et al.,* 2020). Meatballs incorporated with mushrooms showed the increment of hydrogen accommodating ability (Ramle *et al.,* 2021).

3.2 Cooking loss of Pangasius sausage partially replaced by oyster mushrooms in preservation

There was a substantial distinction of cooking loss on the formulated Pangasius sausage partially replaced by oyster mushrooms (0-35%) by the time of storage (Table 3). The more incorporation of oyster mushrooms (0-25%) resulted to lower cooking loss. However, if we continued adding more oyster mushrooms (25-35%), the cooking loss of the formulated sausage became higher. The lowest cooking loss of the formulated sausage was noticed at 8.94±0.01% to 9.50±0.03% during 6-month storage by 25% oyster mushrooms incorporation. Meanwhile, the highest loss of the formulated sausage was noticed at 11.09±0.04% to 11.87±0.04% in the control sample.

Chicken patties showed less cooking loss by the incorporation of mushrooms (Wan Rosli *et al.,* 2011). Pork patties had low cooking loss under the addition of jelly mushrooms (Cha *et al.,* 2014). Chicken sausage incorporated with oyster mushrooms greatly affected cooking loss (Syuhairah *et al.,* 2016). Cooking loss in meat sausage was not significant by 15% mushroom incorporation. At 30% mushroom replacement, the cooking loss of meat sausage was the lowest (Al-Dalain, 2018). Fresh marine catfish sausage incorporated with 10% of smoked pork back fat revealed a low cooking loss (Vieira *et al.,* 2019). Tempeh and white oyster mushrooms were combined with carrageenan to formulate analogue sausage (Septi *et al.,* 2019).

3.3 TBARS value of Pangasius sausage partially replaced by oyster mushrooms during storage

TBARS value was an important indicator of aldehyde content released from lipid rancidity and the represented substance of MDA (Zhao *et al.,* 2020). There

Table 3. Cooking loss (%) of Pangasius sausage partially replaced by oyster mushrooms (%) during storage (months)

Oyster mushrooms (%)	Storage (months)			
	0	2	4	6
0	11.09 ± 0.04^{aC}	11.34 ± 0.03^{aAB}	11.58 ± 0.02^{aAB}	11.87 ± 0.04^{aA}
5	10.81 ± 0.01^{abC}	11.10 ± 0.02^{abAB}	11.32 ± 0.04^{abAB}	11.53 ± 0.03^{abA}
10	10.63 ± 0.03^{bC}	10.94 ± 0.04^{bAB}	11.09 ± 0.01^{bAB}	11.32 ± 0.02^{bA}
15	10.14 ± 0.02^{cC}	10.37 ± 0.01^{cAB}	10.60 ± 0.03^{cAB}	10.83 ± 0.04^{cA}
20	9.71 ± 0.04^{dC}	9.83 ± 0.03^{dAB}	10.09 ± 0.02^{dAB}	10.32 ± 0.01^{dA}
25	8.94 ± 0.01^{eC}	9.12 ± 0.04^{eAB}	9.31 ± 0.01^{eAB}	9.50 ± 0.03^{eA}
30	9.86 ± 0.03^{cdC}	10.08 ± 0.02^{cdAB}	10.36 ± 0.03^{cdAB}	10.61 ± 0.01^{cdA}
35	10.39 ± 0.04^{bcC}	10.62 ± 0.03^{bcAB}	10.85 ± 0.02^{bcAB}	11.07 ± 0.01^{bcA}

Values are presented as mean±SD of triplicates. Values with different lowercase superscript within the same column and values with different uppercase superscript within the same row are significantly different (P<0.05).

https://doi.org/10.26656/fr.2017.7(1).950

was an increasing trend of TBARS value on the formulated Pangasius sausage during storage. By 28% oyster mushrooms incorporation, the lowest TBARS value on the formulated Pangasius sausage was recorded from 0.13±0.00 to 0.52±0.01 (mg malonaldehyde/kg) during 6-month storage. Meanwhile, the highest TBARS value on the formulated Pangasius sausage was recorded from 1.56±0.01 to 2.49±0.01 (mg malonaldehyde/kg) during 6-month storage (Table 4). By 25% oyster mushrooms incorporation, the formulated sausage still maintains the TBARS value within the acceptable limit (< 2 mg malonaldehyde/kg) to overcome bad odour and poor taste accumulation (Connell, 1990). Although oyster mushrooms had several bioactive ingredients that can prevent oxidation in the product, excess inclusion of mushroom powder reduced the hardness, springiness, gumminess, and chewiness of sausage. This would facilitate oxygen penetration into the internal sample.

Decomposition of lipids and proteins in meat and fish patterns is unwanted because it resulted in rancidity, bad smell, abnormal colour on the food commodities (Dominguez *et al.,* 2019; Das, Nanda, Chowdhury *et al.,* 2021). Mushrooms included numerous bioactive substances with natural antioxidant potential beneficial for retardation of rancidity (Chowdhury *et al.,* 2015). The supplementation of oyster mushrooms remarkably reduced the fat content of cooked chicken patties (Wan Rosli and Solihah, 2014). The addition of oyster mushrooms into chicken meat reduced the fat content in frankfurters (Wan Rosli *et al.,* 2015). Mushroom extracts showed antioxidative activities in dry-fermented beef (Genccelep, 2012), pork sausage (Ba *et al.,* 2016), tuna (Bao *et al.,* 2009), kuruma shrimp (Encarnacion *et al.,* 2010). Meat sausage by 30% mushroom substitution showed the lowest TBARS value within 90 days of storage (Al-Dalain, 2018). Fresh rainbow trout sausage formulated with *Laurus nobilis* extract had the lowest amount of TBARS value in 10 days of storage (Ozlem, 2020).

3.4 Overall acceptance of Pangasius sausage partially replaced by oyster mushrooms during storage

There was a substantial distinction of the sensory score on the formulated Pangasius sausage partially replaced by oyster mushrooms (0-35%) by the time of storage. A percentage of 25% oyster mushrooms incorporation was appropriate to maintain the best sensory score (8.79±0.05 to 7.98±0.01) during 6-month storage. Over 25% oyster mushrooms incorporation resulted in a decline in overall acceptance of the formulated sausage (Table 5). Retardation of TBARS value in the substituted fish sausage could be explained by the antioxidant effect of mushrooms (Barros *et al.,* 2011).

Percentage of flesh replacement by mushroom must be appropriate to ensure no major negative impacts on structural properties (Banerjee *et al.,* 2020). A high percentage of mushroom in replacement with muscle decreased the soluble muscle proteins, hence lowering its potential to create firm gel (Das, Nanda, Danpadat *et al.,* 2021). The inclusion of mushroom powder reduced the hardness, springiness, gumminess, and chewiness of sausage (Choe *et al.,* 2018). Incorporation of oyster mushrooms induced to lower hardness of chicken patties (Wan Rosli *et al.,* 2011). Oyster mushrooms added into cuttlefish paste provided surimi gel with lower hardness, cohesiveness, and gumminess but higher overall acceptability (Chung *et al.,* 2010). Chicken frankfurter formulated with 6% oyster mushrooms powder showed more cohesiveness and springiness (Wan Rosli *et al.,* 2015). Mushrooms were compactable to meat-processed commodities due to their umami flavour and fibrous meat-analogue structure (Kumar *et al.,* 2017; He *et al.,* 2020). The umami taste of oyster mushrooms would contribute to the palatability of mono-sodium glutamate and the improvement of overall food acceptance (Jeng-Leun, 2005). An ergothioneine purity from mushroom

Table 4. TBARS (mg malonaldehyde/kg) value of Pangasius sausage partially replaced by oyster mushrooms (%) during storage (months)

Oyster mushrooms (%)	Storage (months)			
	0	2	4	6
0	1.56 ± 0.01^{aC}	1.85 ± 0.02^{aAB}	2.14 ± 0.03^{aAB}	2.49 ± 0.01^{aA}
5	1.43 ± 0.03^{abC}	1.70 ± 0.00^{abAB}	2.01 ± 0.02^{abAB}	2.36 ± 0.03^{abA}
10	1.30 ± 0.01^{bC}	1.56 ± 0.03^{bAB}	1.85 ± 0.00^{bAB}	2.20 ± 0.04^{bA}
15	1.05 ± 0.03^{cC}	1.28 ± 0.02^{cAB}	1.57 ± 0.01^{cAB}	1.93 ± 0.02^{cA}
20	0.81 ± 0.02^{dC}	0.97 ± 0.01^{dAB}	1.29 ± 0.03^{dAB}	1.60 ± 0.00^{dA}
25	0.13 ± 0.00^{eC}	0.22 ± 0.03^{eAB}	0.35 ± 0.02^{eAB}	0.52 ± 0.01^{eA}
30	0.93 ± 0.03^{edC}	1.10 ± 0.01^{cdAB}	1.42 ± 0.00^{cdAB}	1.77 ± 0.03^{cdA}
35	1.19 ± 0.01^{bcC}	1.40 ± 0.00^{bcAB}	1.71 ± 0.03^{bcAB}	2.09 ± 0.02^{bcA}

Values are presented as mean±SD of triplicates. Values with different lowercase superscript within the same column and values with different uppercase superscript within the same row are significantly different (P<0.05).

https://doi.org/10.26656/fr.2017.7(1).950

Table 5. Overall acceptance (sensory score) of Pangasius sausage partially replaced by oyster mushrooms (%) during storage (months)

Oyster mushrooms (%)	Storage (months)			
	0	2	4	6
0	5.57 ± 0.05^{eA}	5.23 ± 0.03^{eAB}	5.01 ± 0.04^{eAB}	4.77 ± 0.02^{eB}
5	5.84 ± 0.03^{deA}	5.60 ± 0.04^{deAB}	5.37 ± 0.01^{deAB}	5.08 ± 0.03^{deB}
10	6.08 ± 0.02^{dA}	5.83 ± 0.01^{dAB}	5.61 ± 0.03^{dAB}	5.38 ± 0.01^{dB}
15	6.81 ± 0.04^{cA}	6.59 ± 0.05^{cAB}	6.33 ± 0.02^{cAB}	6.07 ± 0.04^{cB}
20	7.42 ± 0.01^{bA}	7.13 ± 0.03^{bAB}	6.85 ± 0.04^{bAB}	6.49 ± 0.02^{bB}
25	8.79 ± 0.05^{aA}	8.54 ± 0.02^{aAB}	8.23 ± 0.03^{aAB}	7.98 ± 0.01^{aB}
30	7.13 ± 0.03^{bcA}	6.80 ± 0.04^{bcAB}	6.52 ± 0.02^{bcAB}	6.24 ± 0.03^{bcB}
35	6.40 ± 0.02^{cdA}	6.14 ± 0.03^{cdAB}	5.95 ± 0.05^{cdAB}	5.62 ± 0.04^{cdB}

Values are presented as mean±SD of triplicates. Values with different lowercase superscript within the same column and values with different uppercase superscript within the same row are significantly different ($P<0.05$).

was believed to extend the durability of the red pigment of yellowtail and tuna fish in frozen preservation (Bao *et al.,* 2009). Chicken patties incorporated with oyster mushrooms had decelerated lightness and yellowness (Wan Rosli *et al.,* 2011). Chicken sausage supplemented with oyster mushrooms showed a substantial sensory score as compared to control (Syuhairah *et al.,* 2016). Meat sausage by 30% mushroom substitution showed the highest sensory score within 90 days of storage (Al-Dalain, 2018). Fresh marine catfish sausage incorporated with 10% of smoked pork back fat maintained the high overall acceptance (Vieira *et al.,* 2019). Chicken sausage prepared from partial substitution with raw oyster mushrooms showed high overall acceptance (Faridah and Hun, 2020). Straw mushrooms had a great ability to improve the sensory attributes of sausage (Xuping *et al.,* 2022).

4. Conclusion

Oyster mushrooms was highly preferred in cuisine due to its nutritional proximate, low cholesterol, unique taste, and nutraceutical attributes that could be considered as a promising alternative to partially replace meat and fish in daily consumption. With 30% mushroom incorporation, the Pangasius sausage showed the lowest cooking loss and TBARS value while the highest hydrogen accommodating ability, and overall acceptance. Findings in this research would be very important for seafood processors not only to save production costs and natural resources, minimize pollution but also to produce green healthy food. It was recommended that other edible mushrooms should be investigated to incorporate into meat/ shrimp sausages as well as meat products.

References

Abd-ElGhany, S.M., El-Makhzangy, A.M., El-Shawaf, A.G.M., El-Mougy, R.M. and Sallam, K.I. (2020). Improving safety and quality of Egyptian pastrami through alteration of its microbial community. *LWT*, 118, 108872. https://doi.org/10.1016/j.lwt.2019.108872

Al-Dalain, S.Y.A. (2018). Utilization of mushroom fungi in processing of meat sausage. *Research on Crops,* 19(2), 294-299. https://doi.org/10.5958/2348-7542.2018.00044.X

Alfredo, T., Severiano, S., Cristina, G. and Sandra, R. (2020). Sheep and goat meat processed products quality: A review. *Foods*, 9(7), 960. https://doi.org/10.3390/foods9070960

Alnoumani, H., Ataman, Z.A. and Were, L. (2017). Lipid and protein antioxidant capacity of dried *Agaricus bisporus* in salted cooked ground beef. *Meat Science*, 129, 9–19. https://doi.org/10.1016/j.meatsci.2017.02.010

Anna, R., Monika, S., Jozef, N., Slavomir, M., Boris, S., Milan, C. and Tatiana, K. (2017). Lipid peroxidation process in meat and meat products: a comparison study of malondialdehyde determination between modified 2-thiobarbituric acid spectrophotometric method and reverse-phase high-performance liquid chromatography. *Molecules*, 22(11), 1988. https://doi.org/10.3390/molecules22111988

Aslinah, L.N.F., Yusoff, M.M. and Ismail-Fitry, M.R. (2018). Simultaneous use of adzuki beans (*Vigna angularis*) flour as meat extender and fat replacer in reduced-fat beef meatballs (*Bebola daging*). *Journal of Food Science and Technology*, 55(8), 3241-3248. https://doi.org/10.1007/s13197-018-3256-1

Babatunde, O.A. andrew, B.F. and Elizabeth, B.A. (2021). Effect of cooking oil on the fatty acid profile of beef sausage fortified with edible deboned meat waste. *International Journal of Food Science*, 2021, 5592554. https://doi.org/10.1155/2021/5592554

Banerjee, D.K., Das, A.K., Banerjee, R., Pateiro, M., Nanda, P.K., Gadekar, Y.P., Biswas, S., McClements, D.J. and Lorenzo, J.M. (2020). Application of Enoki mushroom (*Flammulina*

velutipes) stem wastes as functional ingredients in goat meat nuggets. *Foods,* 9(4), 432. https://doi.org/10.3390/foods9040432

Bao, H.N.D., Shinomiya, Y., Ikeda, H. and Ohshima, T. (2009). Preventing discoloration and lipid oxidation in dark muscle of yellowtail by feeding an extract prepared from mushroom (*Flammulina velutipes*) cultured medium. *Aquaculture*, 295(3-4), 243–249. https://doi.org/10.1016/j.aquaculture.2009.06.042

Barros, L., Barreira, J.C.M., Grangeia, C., Batista, C., Cadavez, V.A.P. and Ferrerira I.C.F.R. (2011). Beef burger patties incorporated with *Boletus edulis* extracts: Lipid peroxidation inhibition effects. *European Journal of Lipid Science and Technology*, 113(6), 737-743. http://doi.org/10.1002/ejlt.201000478

Carvalho, L.T., Pires, M.A., Baldin, J.C., Munekata, P.E.S., de Carvalho, F.A.L., Rodrigues, I. and Trindade, M.A. (2019). Partial replacement of meat and fat with hydrated wheat fiber in beef burgers decreases caloric value without reducing the feeling of satiety after consumption. *Meat Science*, 147, 53-59. https://doi.org/10.1016/j.meatsci.2018.08.010

Cha, M.H., Heo, J.Y., Lee, C., Lo, Y.M. and Moon, B. (2014). Quality and sensory characterization of white jelly mushroom (*Tremella fuciformis*) as a meat substitute in pork patty formulation. *Journal of Food Processing and Preservation,* 38(4), 2014–2019. https://doi.org/10.1111/jfpp.12178

Chung, S.I., Kim, S.Y., Nam, Y.J. and Kang, M.Y. (2010). Development of surimi gel from king Oyster mushrooms and cuttlefish meat paste. *Food Science Biotechnol*ogy, 19(1), 51–56. https://doi.org/10.1007/s10068-010-0007-0

Choe, J., Lee, J., Jo, K., Jo, C., Song, M. and Jung, S. (2018). Application of winter mushroom powder as an alternative to phosphates in emulsion-type sausages. *Meat Science,* 143, 114–118. https://doi.org/10.1016/j.meatsci.2018.04.038

Choe, J. and Kim, H.Y. (2019). Quality characteristics of reduced fat emulsion-type chicken sausages using chicken skin and wheat fiber mixture as fat replacer. *Poultry Science*, 98(6), 2662-2669. https://doi.org/10.3382/ps/pez016

Chowdhury, H.M.H., Kubra, K. and Ahmed, R.R. (2015). Screening of antimicrobial, antioxidant properties and bioactive compounds of some edible mushrooms cultivated in Bangladesh. *Annals of Clinical Microbiology and Antimicrobiology*, 14, 8. https://doi.org/10.1186%2Fs12941-015-0067-3

Chye, F.Y., Wong, J.Y. and Lee, J.S. (2008). Nutritional quality and antioxidant activity of selected edible wild mushrooms. *Food Science and Technology International*, 14(4), 375-384. https://doi.org/10.1177%2F1082013208097445

Connell, J.J. (1990). Control of fish quality. 3rd ed. Oxford, United Kingdom: Fishing News Books.

Das, A.K., Nanda, P.K, Chowdhury, N.R., Dandapat, P., Gagaoua, M., Chauhan, P., Pateiro, M. and Lorenzo, J.M. (2021). Application of pomegranate by-products in muscle foods: oxidative indices, colour stability, shelf life and health benefits. *Molecules*, 26 (2), 467. https://doi.org/10.3390/molecules26020467

Das, A.K., Nanda, P.K., Dandapat, P., Bandyopadhyay, S., Gullon, P., Sivaraman, G.K., McClements, D.J., Gullon, B. and Lorenzo, J.M. (2021). Edible mushrooms as functional ingredients for development of healthier and more sustainable muscle foods: A flexitarian approach. *Molecules*, 26 (9), 2463. https://doi.org/10.3390/molecules26092463

Drewnowski, A. (2018). Nutrient density: addressing the challenge of obesity. *British Journal of Nutrition*, 120(Suppl. 1), S8-S14. https://doi.org/10.1017/s0007114517002240

Dominguez, R., Pateiro, M., Gagaoua, M., Barba, F.J., Zhang, W. and Lorenzo, J.M. (2019). A comprehensive review on lipid oxidation in meat and meat products. *Antioxidants*, 8(10), 429. https://doi.org/10.3390/antiox8100429

Dosh, K.S., Tawfiq, N.N. and Jabbar, S.H. (2016). Preparation of modified chicken burger by partial replacement of chicken meat with powdered of Oyster mushrooms and study it is physical and sensory properties. *The Iraqi Journal of Agricultural Sciences*, 47(7), 138-143.

Emy, Y. and Kamsiah (2018). The formulation of analog sausage with high protein and cork sea fiber (*Channa striata*), and Oyster mushrooms as the healthy snacks for the school children. *Advances in Health Sciences Research*, 14, 192-203. https://doi.org/10.2991/icihc-18.2019.46

Encarnacion, A.B., Fagutao, F., Hirono, I., Ushio, H. and Ohshima, T. (2010). Effects of ergothioneine from mushrooms (*Flammulina velutipes*) on melanosis and lipid oxidation of kuruma shrimp (*Marsupenaeus japonicus*). *Journal of Agriculture and Food Chemistry*, 58(4), 2577–2585. https://doi.org/10.1021/jf903944y

Faridah, Y. and Hun, T.T. (2020). Effect of different ratios of chicken meat to fresh oyster mushroom (*Pleurotus sajor-caju*) on the physicochemical properties and sensory acceptability of sausages. *International Journal on Food, Agriculture, and Natural Resources,* 1(1), 7-14. https://doi.org/10.46676/ij-fanres.v1i1.2

Genccelep, H. (2012). The effect of using dried mushroom (*Agaricus bisporus*) on lipid oxidation and color properties of sucuk. *Journal of Food Biochemistry*, 36(5), 587–594. https://doi.org/10.1111/j.1745-4514.2011.00570.x

He, J., Evans, N.M., Liu, H. and Shao, S. (2020). A review of research on plant-based meat alternatives: Driving forces, history, manufacturing, and consumer attitudes. *Comprehensive Review of Food Science and Food Safety*, 19(5), 2639–2656. https://doi.org/10.1111/1541-4337.12610

Jeng-Leun, M. (2005). The umami taste of edible and medicinal mushrooms. *International Journal of Medicinal Mushrooms*, 7(1), 119–125. http://doi.org/10.1615/IntJMedMushr.v7.i12.120

Jo, K., Lee, J. and Jung, S. (2018). Quality characteristics of low-salt chicken sausage supplemented with a winter mushroom powder. *Korean Journal of Food Science and Animal Resources*, 38(4), 768–779. https://doi.org/10.5851%2Fkosfa.2018.e15

Kakon, A., Choudhury, M.B.K. and Saha, S. (2012). Mushroom is an ideal food supplement. *Journal of Dhaka National Medical College Hospital*, 18(1), 58–62. http://doi.org/10.3329/jdnmch.v18i1.12243

Kumar, P., Chatli, M.K., Mehta, N., Singh, P., Malav, O.P. and Verma, A.K. (2017). Meat analogues: Health promising sustainable meat substitutes. *Critical Review of Food Science and Nutrition,* 57 (5), 923–932. https://doi.org/10.1080/10408398.2014.939739

Lu, X., Brennan, M.A., Narciso, J., Guan, W., Zhang, J., Yuan, L., Serventi, L. and Brennan, C.S. (2020). Correlations between the phenolic and fibre composition of mushrooms and the glycaemic and textural characteristics of mushroom enriched extruded products. *LWT*, 118, 108730. https://doi.org/10.1016/j.lwt.2019.108730

Marina, C.S., Dyego, L.S., Anna, V.M. and Miriam, T.M. (2021) Effect of pork back-fat reduction and substitution with texturized pea protein on acceptability and sensory characteristics of dry fermented sausages. *CyTA - Journal of Food*, 19 (1), 429-439. https://doi.org/10.1080/19476337.2021.1912188

Mehta, N., Ahlawat, S.S., Sharma, D.P. and Dabur, R.S. (2015). Novel trends in development of dietary fiber rich meat products—a critical review. *Journal of Food Science and Technology*, 52(2), 633-647. https://doi.org/10.1007/s13197-013-1010-2

Minh, N.P. (2021). Synergistic effect of Gac (*Momordica cochinchinensis* Spreng) and turmeric (*Curcuma longa*) extract on microbiological, physicochemical, and organoleptic properties of fermented *Pangasius* sausage. *Bioscience Research*, 18(1), 921-928.

Minh, N.P., Pham, V.T., Thuy, T.T., Phien, L.T.N. and Thai, T.D. (2019). Different parameters in development and evaluation of dry fermented sausages processed from blends of broken shrimp and bronze featherback (*Notopterus notopterus*) meat. *Journal of Pharmaceutical Sciences and Research*, 11(4), 1422-1426.

Minh N.P. and Nga N.H. (2018). Different conditions impacting to physicochemical properties and sensory characteristics of bronze featherback sausage. *International Journal of Applied Engineering Research*, 13(2), 1328-1331.

Moon, B. and Lo, Y.M. (2014). Conventional and novel applications of edible mushrooms in today's food industry. *Journal of Food Processing and Preservation,* 38(5), 2146-2153. https://doi.org/10.1111/jfpp.12185

Nayak, P.C., Raju, C.V., Lakshmisha, I.P., Singh, R.R. and Sofi, F.R. (2015). Influence of Button mushroom (*Agaricus bisporus*) on quality and refrigerated storage stability of patties prepared from sutchi catfish (*Pangasius hypophthalmus*). *Journal of Food Science and Technology*, 52(6), 3529–3538. https://doi.org/10.1007/s13197-014-1415-6

Ozlem, E.C. (2020). Production of fresh fish sausages containing natural preservatives (*Laurus nobilis* L.) it's nutritional composition and oxidative stability. *Progress in Nutrition,* 22(2), 501-506. https://doi.org/10.23751/pn.v22i2.8912

Poore, J. and Nemecek, T. (2018). Reducing food's environmental impacts through producers and consumers. *Science*, 360(6392), 987–992. https://doi.org/10.1126/science.aaq0216

Rai, A.K., Chakravorty, R. and Paul, J. (2008). Detection of Giardia, Entamoeba, and Cryptosporidium in unprocessed food items from northern India. *World Journal of Microbiology and Biotechnology,* 24(12), 2879–2887. http://doi.org/10.1007/s11274-008-9824-1

Rai, A.K., Palni, U. and Tamang, J.P. (2009). Traditional knowledge of the ethnic Himalayan people on production of indigenous meat products. *Indian Journal Traditional Knowledge*, 8(4), 586–591.

Raju, C.V., Shamasundar, B.A. and Udupa, K.S. (2003). The use of nisin as a preservative in fish sausage stored at ambient (28±2°C) and refrigerated (6±2°C) temperatures. *International Journal of Food Science and Technology,* 38(2), 171–185. http://doi.org/10.1046/j.1365-2621.2003.00663.x

Ramle, N.A., Zulkurnain, M. and Ismail-Fitry, M.R.

(2021). Replacing animal fat with edible mushrooms: a strategy to produce high-quality and low-fat buffalo meatballs. *International Food Research Journal*, 28(5), 905 – 915.

Saricoban, C., Karakaya, M. and Caner, C. (2006). Properties of Turkish style sucuk made with different combinations of beef and hen meat. *Journal of Muscle Foods,* 17(1), 1–8. http://doi.org/10.1111/j.1745-4573.2006.00027.x

Septi, R., Akhmad, M. and Yannie, A.W. (2019). Analogue sausage formulation of tempeh-white Oyster mushrooms (*Pleurotus ostreatus*) with the addition of carrageenan. *Food ScienTech Journal*, 1 (1), 24-30. https://doi.org/10.33512/fsj.v1i1.6194

Stajic, S., Perunovic, M., Stanisic, N., Zujovic, M. and Zivkovic, D. (2012). Sucuk (Turkish-style dry-fermented sausage) quality as an influence of recipe formulation and inoculation of starter cultures. *Journal of Food Processing and Preservation,* 37(5), 870–880. https://doi.org/10.1111/j.1745-4549.2012.00709.x

Stephen, D. (2009). Mushroom extract shows promise for meat preservative. *Journal of Food Science*, 2009, 1750.

Svanberg, I. (2015). Ræstur fiskur: Air-dried fermented fish the Faroese way. *Journal of Ethnobiology and Ethnomedicine*, 11, 76. https://doi.org/10.1186/s13002-015-0064-9

Synyttsya, A., Mickova, K., Jablonsky, I., Slukova, M. and Copikova, J. (2008). Mushroom of genus *Pleurotus* as a source of dietary fibres and glucans for food supplements. *Czech Journal of Food Science*, 26(6), 441-446.

Syuhairah, A., Huda, N., Syahariza, Z.A. and Fazilah, A. (2016). Effects of vegetable incorporation on physical and sensory characteristics of sausages. *Asian Journal of Poultry Science,* 10(3), 117-125. https://doi.org/10.3923/ajpsaj.2016.117.125

Ba, H.V. Seo, H.W., Cho, S.H., Kim, Y.S., Kim, J.H., Ham, J.S., Park, B.Y. and Nam, S.P. (2016). Antioxidant and anti-foodborne bacteria activities of shiitake by-product extract in fermented sausages. *Food Control,* 70, 201–209. https://doi.org/10.1016/j.foodcont.2016.05.053

Vieira, P.H.S., Barros, C.N.de, Mendes, E.S., Maciel, M.I.S. Andrade, H.A.de. and Oliveira Filho, P.R.C.de. (2019). Development and characterization of fresh sausages made with marine catfish Sciades herzbergii (Bloch, 1794). *Acta Scientiarum. Technology*, 41(1), e40299. https://doi.org/10.4025/actascitechnol.v41i1.40299

Xuping, W., Pengfei, Z., Jingrong, C., Huaigu, Y., Jinhao, Z. and Xueming, L. (2022). The role of endogenous enzyme from straw mushroom (*Volvariella volvacea*) in improving taste and volatile flavor characteristics of Cantonese sausage. *LWT*, 154(15), 112627. https://doi.org/10.1016/j.lwt.2021.112627

Wan Rosli, W.I., Solihah, M.A., Aishah, M., Nik Fakurudin, N.A. and Mohsin, S.S.J. (2011). Colour, textural properties, cooking characteristics and fibre content of chicken patty added with Oyster mushrooms (*Pleurotus sajor-caju*). *International Food Research Journal*, 18(2), 621-627.

Wan Rosli, W.I. and Solihah, M.A. (2014). Nutritional composition and sensory properties of Oyster mushrooms-based patties packed with biodegradable packaging. *Sains Malaysia*, 43(1), 65–71.

Wan Rosli, W.I., Nor Maihiza, M.S. and Raushan, M. (2015). The ability of Oyster mushrooms in improving nutritional composition, β-glucan, and textural properties of chicken frankfurter. *International Food Research Journal*, 22(1), 311-317.

Wang, L., Guo, H., Liu, X., Jiang, G., Li, C., Li, X. and Li, Y. (2019). Roles of *Lentinula edodes* as the pork lean meat replacer in production of the sausage. *Meat Science*, 156, 44-51. https://doi.org/10.1016/j.meatsci.2019.05.016

Wangteui, S., Maneerote, J., Seesuriyachan, P., Phimonsiripol, Y., Laokuldilok, T., Surawang, S. and Regenstein, J.M. (2020). Combination effects of phosphate and NaCl on physiochemical, microbiological, and sensory properties of frozen Nile Tilapia (*Oreochromis niloticus*) fillets during frozen storage. *Walailak Journal of Science and Technology*, 17(4), 313–323. https://doi.org/10.48048/wjst.2020.4540

Zeng, W., Wen, W., Deng, Y., Tian, Y., Sun, H. and Sun, Q. (2016). Chinese ethnic meat products: Continuity and development. *Meat Science,* 120, 37–46. https://doi.org/10.1016/j.meatsci.2016.04.007

Zhang, Y., Venkitasamy, C., Pan, Z. and Wang, W. (2013). Recent developments on umami ingredients of edible mushrooms—A review. *Trends Food Science and Technology*, 33(2), 78–92. https://doi.org/10.1016/j.tifs.2013.08.002

Zhao, B., Zhou, H., Zhang, M., Liang, S., Pan, X.Q. and Li, S. (2020). Changes of protein oxidation, lipid oxidation and lipolysis in Chinese dry sausage with different sodium chloride curing salt content. *Food Science and Human Wellness,* 9(4), 328-337. https://doi.org/10.1016/j.fshw.2020.04.013

https://doi.org/10.26656/fr.2017.7(1).950